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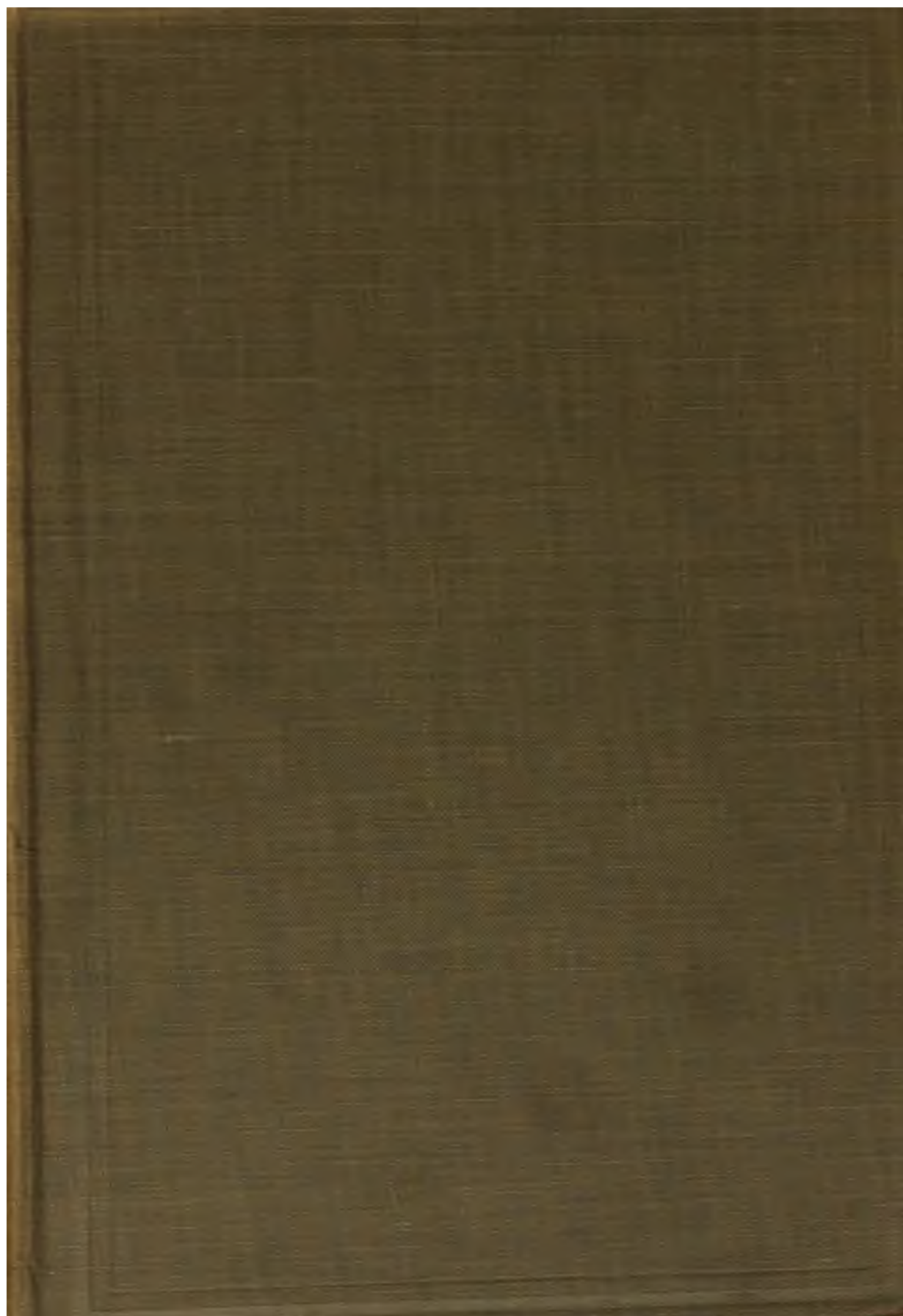
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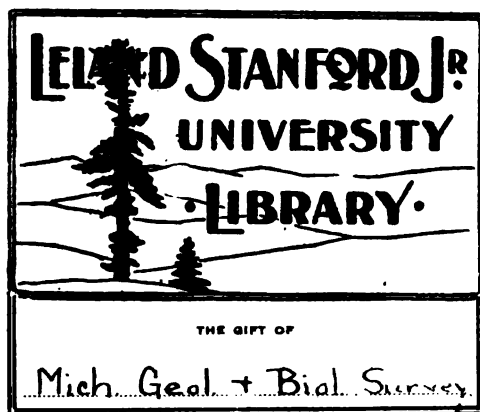
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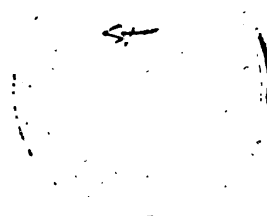
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MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

Publication 14.
Geological Series 11.

THE OCCURRENCE OF OIL AND GAS IN MICHIGAN

BY
RICHARD A. SMITH



PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF
GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1912.

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LETTER OF TRANSMITTAL.

To the Honorable the Board of Geological and Biological Survey of the State of Michigan:

GOV. WOODBRIDGE N. FERRIS, President.
HON. WM. J. MCKONE, Vice-President.
HON. FRED L. KEELER, Secretary.

Gentlemen:—

I have the honor to present herewith Publication 14, Geological Series 11, a monograph on the subject of the occurrence of oil and gas in Michigan. The recent activity in drilling for oil and gas has not only stimulated the issue of this volume but has also contributed directly to the information contained in it. Much of the data contained in this work is new, including the records of a considerable number of important deep wells, but a large part of it has been compiled from various sources.

For many years the Southern Peninsula of Michigan has offered a tempting field for exploratory work designed to test the possibilities for the occurrence of oil and gas. Although with the minor exception of the Port Huron field all such efforts have resulted in a discouraging monotony of disappointments; the activities of recent years lends force to the observation that repeated failures serve only to stimulate rather than to retard these adventurous projects.

The time is approaching if not actually at hand in most parts of this country, when valuable mineral deposits may be found no longer without the application of vast labor and expense to underground explorations of one or another kind. Surely this is true of the State of Michigan, and probably nowhere within our borders may success attend the efforts of the prospector unaided by generous financial support. Any project devoted to the discovery of valuable minerals must therefore be considered as a purely financial adventure and this applies with peculiar force to explorations for oil and gas in Michigan.

It is trite to remark that a financial adventure should be preceded and controlled by a careful weighing of the possibilities for success. This is a moral as well as a business responsibility which is particularly incumbent on those who control the expenditure of the capital

of a company, association, or corporation. Unfortunately this responsibility has been so frequently violated through fraudulent intent in some instances and ignorance in others, that a warning should be sounded throughout the state as a guard not only against fraudulent schemes of promotion, but against that credulous class of so-called "oil smellers" or "locators" whose operations are no less fantastic than their claims to unusual or occult powers are crass and audacious. The "oil smeller" or "locator" is not always a calculating fakir. Among them are a few who seem to be honest but these present a curious study of more interest to the psychologist than to the geologist, and to the former they may be consigned without further remark.

The professional promotor, when guided by moral as well as business sense, is a legitimate and oftentimes necessary factor in many modern financial and industrial undertakings, but the element of mere luck or chance, which the partial and oftentimes complete absence of determinative data in many localities must always leave open to the prospector, not only provides a cloak for rascality but also a basis for the play of credulous imagination on which the unscrupulous promotor builds his fortune. Men of sound judgment in matters of general business, as well as others, continue to seek pots of gold at the end of the rainbow, following those whose sole claims to leadership reside in unscrupulousness, suave audacity, clever deceitfulness, and a smattering of technical jargon, meaningless to themselves but nevertheless a bait for the unwary layman.

As may be suspected, the promoter and the "locator" often share the work as well as the gains attaching to a successful "fleecing" of a whole community. In many instances, their common solicitude for a wider distribution of prosperity invites a participation of the people in general through the medium of carefully prepared "literature" amply illustrated with pictures of derricks, drilling outfits, views in the oil fields, gushers, and perhaps a sketch showing the exact position of the "vein" or "pool" which is expected to be opened by the application of the stockholders' money if enough remains for the purpose after promotion charges have been carefully set aside. Lacking only the actual odor of crude oil, which can hardly be transmitted by mail, these gems of persuasive advertising are calculated to produce an anticipation of realities which are doomed to materialize only in the imaginations of the investors.

Among the numerous drilling operations of recent years are a number which may be termed "community projects." The incentive to these undertakings is a general desire for exact information relative to the formations and their contents coupled with a hope, not to say expectation, of developing a valuable local resource. Such efforts

should be encouraged, but only under a full realization of the relative probabilities for financial loss or gain on the part of those whose means are involved. None who can ill afford the risk of loss should be encouraged to enlist in these enterprises.

Those who engage permanently in the oil business recognize the principle that the chances for loss are in inverse ratio to the number of well advised separate adventures embraced. A small amount of money staked on a single, or a limited number of projects is almost certain to be dissipated. On the other hand, a large amount of money involved in many separate and well advised operations is almost equally certain to be multiplied. To illustrate this principle, it may be remarked that a single well drilled in the most favorable locality in Michigan would have only a very remote possibility of encountering oil in commercial quantity, but the drilling of one hundred wells in five favorable localities would stand a very reasonable, though far from assured, chance of success. A thousand dollars invested in the latter enterprise would be a much sounder investment than the same amount invested in the former. It is the operation of this principle which renders so extremely hazardous an occasional investment in operations confined to a single test well, or a single locality.

The natural conditions governing the occurrence of oil and gas are well known to geologists, but unfortunately the geologic data in different regions or localities are rarely so precise and determinate as to warrant unqualified statements in the one or the other direction in advance of exploration. There is a large area in Michigan where oil or gas is not to be sought under any circumstances because of the age and character of the rocks. I refer to the copper and iron bearing region of the Northern Peninsula; i. e., that part of the state underlain by pre-Cambrian rocks. In a considerable part of the remainder of the State the occurrence of oil and gas in commercial quantity is a possibility and in some localities a very reasonable probability. Common prudence would demand that the areas where the conditions are known to be favorable should receive first attention through a fair and adequate test. Too frequently, initial disappointments terminate a well conceived plan of exploration before conclusive results either positive or negative are obtained. Negative results are always ultimately if not immediately useful, and, therefore, records of all explorations should be carefully preserved.

It has been remarked above that the absence of ample and reliable data, from which the geologist may draw sound conclusions, and the element of luck or chance renders unsafe in many parts of Michigan any unqualified statement relative to the presence or absence of commercial quantities of oil or gas, but while the soundness of any calcula-

tion or conclusion must always be governed largely by the fullness and reliability of the basal data, the lack of complete information need not stay a conclusion or hypothesis on which to base expenditures in exploration. Indeed ultra conservatism is rarely creative; it is desirable only to eliminate waste through ignorance or fraud and on the other hand to encourage and assist worthy projects for exploration. It is with this double purpose in view that this volume has been presented to the public. If it accomplishes these purposes the care, labor, and expense which has been devoted to it will have been well repaid.

Very respectfully yours,

R. C. ALLEN,

Director.

June 18, 1914.

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INTRODUCTION.

In 1860, A. Winchell, published in the First Biennial Report of the Geological Survey of Michigan a number of records of deep borings and referred to the possibilities for the occurrence of oil in the eastern part of the State, especially in the vicinity of Port Huron. Further records of borings were given in Volume III by Dr. C. Rominger in a report on the geology of the Lower Peninsula of Michigan. In Volume V, Dr. A. C. Lane published a large number of well sections with special reference to the occurrence of oil and gas. The introduction, written by Dr. L. L. Hubbard, is a brief discussion of the origin of salt, gypsum, and *petroleum*. Brief chapters on oil and gas together with the records of many borings were published by Lane in the Annual Reports for 1901, 1903, 1904, and 1908. The Mineral Resources for 1911, Publication 8, Geological Series 6, contains a short chapter on the occurrence of oil and gas in Michigan.

The above reports contain most of the published information with the exception of that to be found in the geological reports of the various counties.

Since Michigan lies adjacent to the oil and gas producing territories of Ontario, Ohio, and Indiana, it has received for many years much attention from oil and gas operators. Many explorations have been made, but thus far the results have been meager. Only at Port Huron, Allegan, and Saginaw have oil and gas been struck in quantities approaching commercial importance. The known presence of oil formations, the many small showing of oil and gas, and the abundance of oil and especially gas seepage in certain portions of the State, however, have kept up a keen interest in the possibilities for the occurrence of oil and gas in larger quantities. During the past three years especially, there has been a continuous demand on the part of the oil operators and the general public for information relative to the oil and gas possibilities in Michigan, and fifty or more drilling operations have been made and projected.

A large part of the recent drillings were located with due regard to known geological conditions, but unfortunately a considerable number of explorations were started upon the most chimerical notions of geology, which is not surprising when it is considered that most of the explorations in Michigan have been made by operators from the oil fields of adjacent states.

The data furnished by the many explorations of recent years has been published only in part. The object of this report is to bring together all the available data relative to the occurrence of oil and gas in Michigan in such a form as to make it effective in more intelligently directing explorations.

The plan of the report embraces, (1) An outline of the geology of the Paleozoic formations, (2) A brief discussion of the more prominent theories on the accumulation of oil and gas, but more particularly of the anticlinal theory of accumulation, (3) A history of the explorations by districts or fields with the records of borings, (4) A discussion of the care and regulation of oil and gas wells and an outline of needed legislation relative to deep borings, and (5) A brief statement of the possibilities of the black shales of Michigan as a source of oil and gas.

The well records given in detail do not include all of the deep borings in the Paleozoic area. Many wells have been drilled of which the Geological Survey has no records, or only imperfect ones. At many places, several borings have been closely spaced, and of these only the more accurate records have been given, but whatever information the others afford has been included in the discussions preceding the records given. Most of the records have been revised, especially the older ones, to bring them into harmony with present geologic knowledge.

For convenience in discussing the history of the oil explorations, the state has been arbitrarily divided into districts and fields. As there are no sharp lines of separation between any of these, some wells included in one district may have been placed with equal propriety in another. The territory in the vicinity of Saginaw and of Port Huron, properly parts of the central and the southeastern districts respectively, have been deemed worthy of separate treatment as oil fields on account of the structural conditions and the large amount of exploration made in each.

In all oil fields, there is always a greater or less number of "dry" holes or wells of small production which are abandoned. Usually the drillings pass through one or more water or brine bearing formations and the "dry" holes and abandoned wells form a serious menace to the life and productivity of a field through the ingress of water into the oil sands. On the other hand, oil and gas wells are a source of danger to mining industries, but more especially to that of coal, through the escape of gas into the mines with consequent explosion. So acute is the situation in some states that stringent laws have been passed regulating the drilling and care of oil and gas wells. Besides being a source of injury to oil fields and a menace to life and property in coal mining regions, abandoned wells, in some cases, cause contami-

nation of potable water supplies through the entrance of salt water; or, vice versa, valuable brines or mineral waters may be polluted by surface or fresh waters.

In Saginaw Valley and in the vicinity of Grand Rapids, the potable waters have been ruined through the ingress of brines or mineral waters, and the purity and strength of the brines in the former district are now being menaced by the entrance of surface or fresh waters through abandoned salt wells, the casings of which have been destroyed by the corrosive action of the brines. The regulation and care of oil and gas and other borings has become a subject of such importance to the State that a discussion of the methods and means of conserving oil and gas, water, and other mineral resources has been included as an appendix to this report.

ACKNOWLEDGMENTS.

The information contained in this report has been compiled from so many sources that proper acknowledgment cannot be made to each of the investigators whose works have been freely drawn upon. The outline of the geology of the Michigan Basin has been taken largely from the writings of A. C. Lane, C. Rominger, and A. Winchell. The stratigraphy of the formations has been compiled chiefly from Lane's Geological Section as published in the Annual Report for 1908. Much information on local geology has been afforded by the reports on Huron and Alcona counties by A. C. Lane, on Monroe and Wayne counties by W. S. Sherzer, on Sanilac by C. H. Gordon, on Bay by W. F. Cooper, on Tuscola by C. A. Davis, and on Arenac by W. M. Gregory.

The various bulletins of the U. S. Geological Survey and the State geological reports have been freely consulted for the material in the chapter on the accumulation of oil and gas. The statement and the history of the development of the anticlinal theory with particular reference to its practical application has been compiled from the publications of I. C. White and E. Orton.

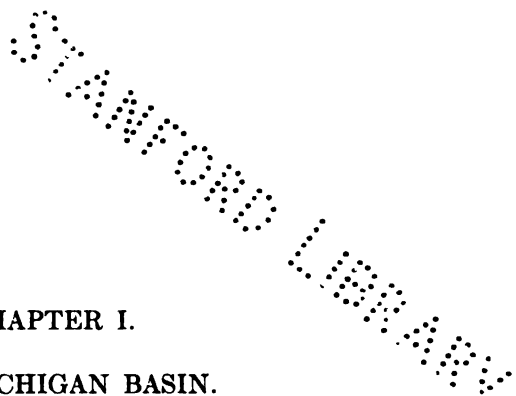
Much other information bearing upon the limitations of the anticlinal theory has been gleaned from the investigations of N. M. Fenneman, F. G. Clapp, R. W. Stone, M. J. Munn, W. T. Griswold, H. S. Gale, R. Arnold, C. W. Hayes, Wm. Kennedy, C. H. Wegeman, and others as found in the many bulletins published by the U. S. Geological Survey.

The history of the drillings and the records have been compiled from the several reports of the Michigan Geological Survey, particularly Volumes V, VII, and VIII, the Annual Reports for 1901, 1903, 1904, and 1908, and Publications 2, 12, and 15. Many of the records

were previously unpublished, or published only in part. In compiling these, much valuable information was obtained from the field notes of Dr. A. C. Lane and W. F. Cooper. Special acknowledgment is hereby extended to the officials of the Saginaw Development Company for their many courtesies and hearty co-operation in carefully preserving sets of samples and compiling the information afforded by their drillings in the vicinity of Saginaw.

Most of the information in Appendix A on the regulation and care of deep borings has been obtained from Bulletin 65 and Technical Paper 53 of the U. S. Bureau of Mines. Much other data, however, has been gleaned from the reports of the State geological surveys and of the State mine or oil and gas inspectors, particularly of California, Oklahoma, Ohio, Indiana, and Wyoming.

In the discussion of the commercial possibilities of the black or bituminous shales in Appendix B, much valuable information was obtained from the Summary Reports, and especially from the Joint Report on the Bituminous or Oil Shales of New Brunswick and Nova Scotia and on the oil Shale Industry of Scotland by R. W. Ells, Nos. 55 and 1107 of the Mines and Geological Survey Branches of the Department of Mines of Canada. It is to be regretted that the writer did not have the opportunity of reading the bulletin now in preparation by the U. S. Geological Survey on the Oil Shales of Utah and Colorado.



CHAPTER I.

THE MICHIGAN BASIN.

MAJOR STRUCTURE.

The term, *Michigan Basin*, is applied to a broad, shallow structural basin occupying part of western Ontario, the eastern half of the Northern and the whole of the Southern Peninsula of Michigan, eastern Wisconsin, northeastern Illinois, northern Indiana, and northwestern Ohio. Its average diameter is about 500 miles and the deepest part appears to be near the geographical center of the Southern Peninsula. The total depression of the lowermost Paleozoic formations at the center has been variously estimated at from 5000 to 7000 feet. Recent drillings in the central part of the Basin favor the larger figure.

The Michigan Basin is a composite, comprising a series of sedimentary formations which form a gigantic nest of very broad and extremely shallow warped basins whose diameters decrease regularly from the bottom upward (Fig. 1.) Were the rims of these basins uncovered by draining the lake basins and removing the glacial drift, they would form concentric belts about the central or uppermost formation (Fig. 2.) The depth of the Basin is so small in comparison with its diameter that the inclination of its several members is ordinarily between 25 and 50 feet per mile, and rarely exceeds 60 feet.

MINOR STRUCTURES.

The formations constituting the Michigan Basin are locally gently folded and, in some cases, slightly faulted. So far as known, the folds occur mainly near the margin of the Southern Peninsula and in Western Ontario. Of the anticlines or upward folds (Fig. 2), the six best developed ones in the Southern Peninsula are in the vicinity of Saginaw, Port Huron, Stony Island (Detroit river), Wyandotte, Niles, and Khagashewing Point (Little Traverse Bay). A very low, broad and ill defined anticline extends through Washtenaw county with its crest apparently near Ann Arbor. All of the anticlines, excepting those near Saginaw, Niles, and Ann Arbor, are relatively low and short. (See Chaps. IV, V and VII). Inconclusive evidence points to the probable existence of additional anticlines in the vicinity of New Baltimore, Macomb county, near Manistee, and near Fowler-

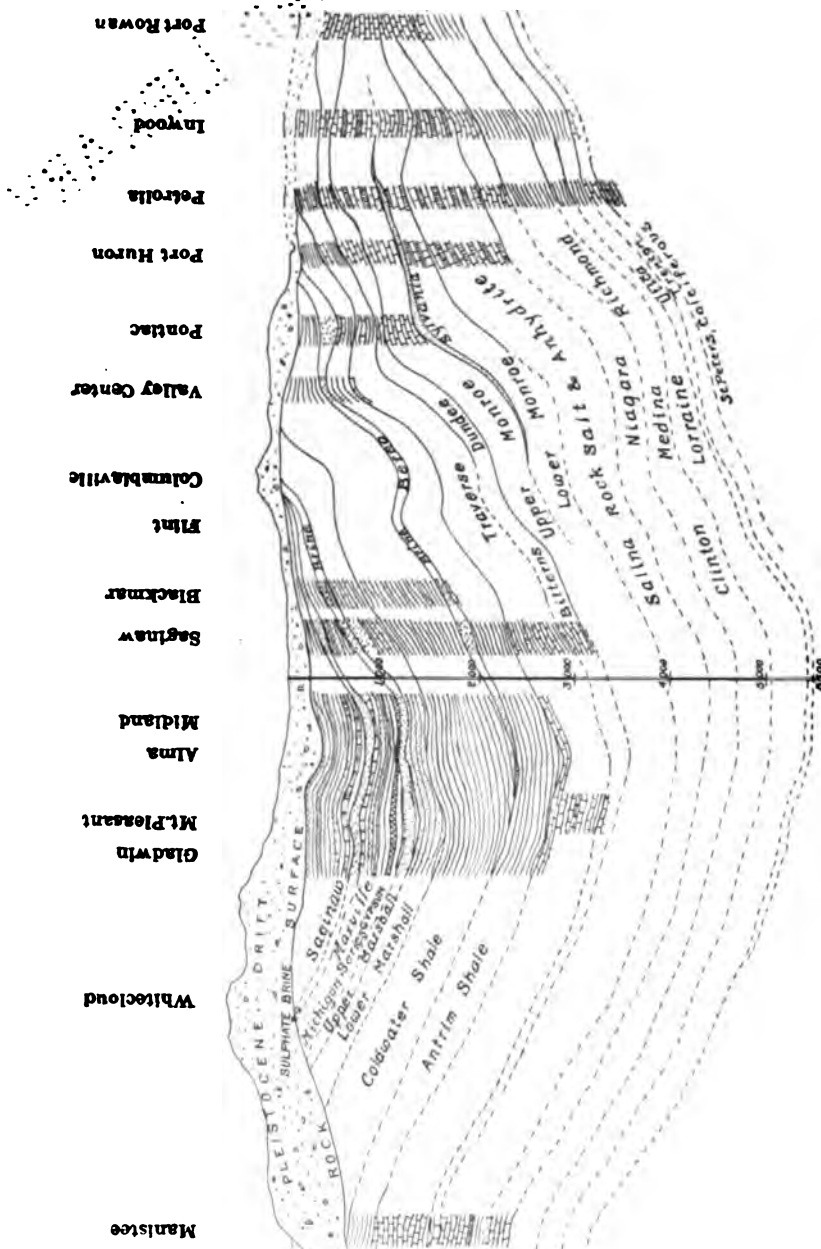
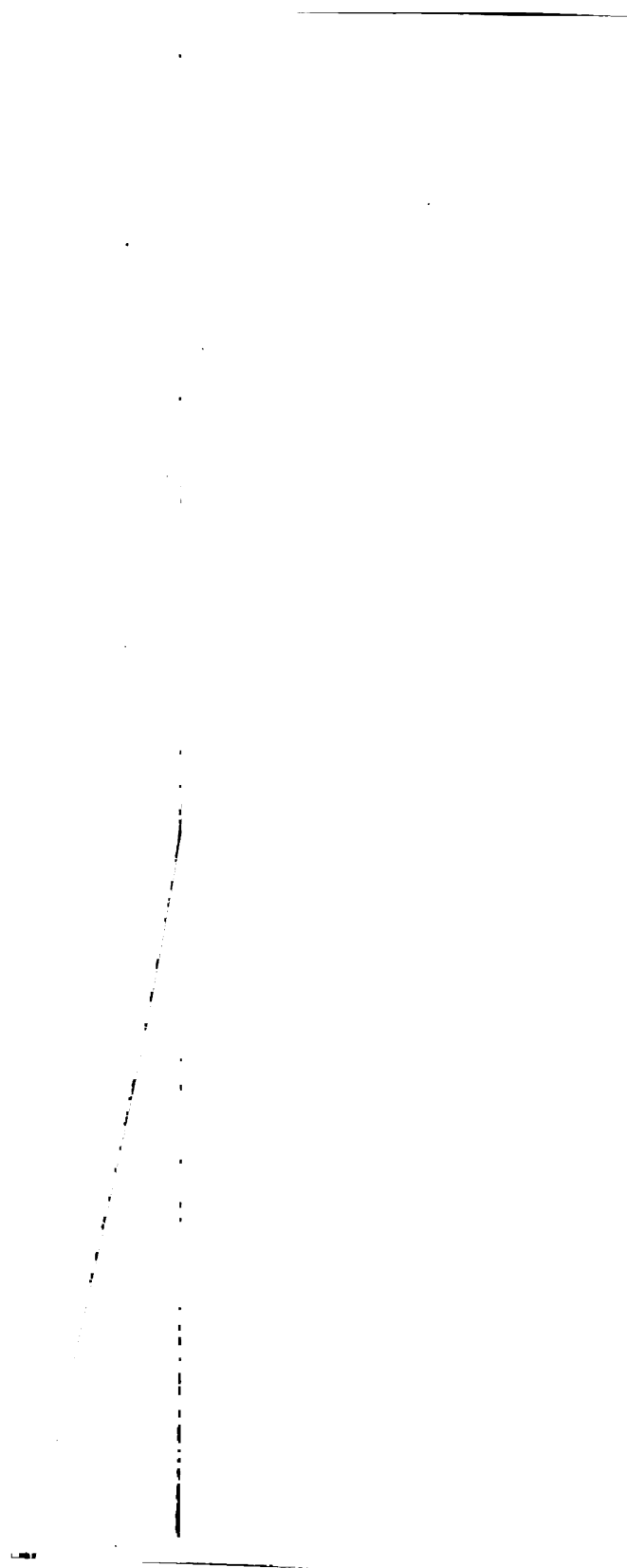


Figure 1. Diagrammatic cross section of the Michigan Basin from Port Rowan, Ontario to Manistee, Michigan.





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ville and Howell, Livingston county. A syncline of considerable length and depth occurs near Berrien Springs and Dowagiac in Berrien county and two or three small ones¹ along Detroit river south of Detroit. Doubtless further drilling will reveal the presence of other anticlines and synclines of which there is now no indication.

In the vicinity of Alean, there is a sudden change in the general northeastward dip of the strata, indicating the presence of a terrace or structural "bench." Discordant dips have been observed in several places in southeastern Michigan, in Huron, Alpena, and Presque Isle counties, and along the Lake Michigan and Lake Huron shores of the Northern Peninsula.

Numerous faults, generally with a displacement of a few inches to a few feet, have been noted in the Coal Measures. However, the occurrence of two faults with displacements of 50 to 60 feet have been reported, one in the Coal Measures of Saginaw Valley, and the other in the Dundee limestone in Presque Isle county. The Monroe formation in southeastern Michigan and in the Northern Peninsula is characterized by peculiarly brecciated dolomites. Drillings in the Manistee-Ludington salt district and in Presque Isle county indicate a wide spread occurrence of this brecciation, the cause of which may be related to movements due to the ablation of the salt beds as noted in Chapter IX.

THE GEOLOGICAL SECTION.

The rocks of the Michigan Basin represent the Paleozoic succession from the base of the Upper Cambrian to near the top of the Pennsylvanian. Exposures are numerous in many localities, especially along the north and south shores of the Northern Peninsula, but, in areas of large extent in the Southern Peninsula, outcrops are entirely wanting. In the Southern Peninsula, bed rock is exposed in two areas of considerable extent, one in Alpena and Presque Isle counties, and the other in Hillsdale and southern Calhoun and Jackson counties. Scattered outcrops occur in an arcuate belt extending from Arenac county through Huron and Tuscola into Genesee county, and from Jackson county through Calhoun into Ottawa and Kent counties. Limited but important outcrops also occur along the south shore of Little Traverse Bay and in Monroe and Wayne counties. In the greater part of the State, however, the Paleozoic rocks are concealed by a mantle of drift from 100 to 600 feet or more in thickness and the knowledge of the structure, character, distribution, and thickness of the different formations, necessary for making a generalized section, has been derived chiefly from a study of the records of borings.

¹W. H. Sherzer: *The Monroe Formation*, Pub. 2, Geol. Ser. 1, p. 57.

CAMBRIAN.

Lake Superior, Eastern or Jacobsville sandstone. The Cambrian, so far as known, is represented in Michigan by the upper member only, called the Lake Superior or Potsdam sandstone. Jacobsville (or "Eastern") is the term applied to a similar sandstone along Keweenaw Bay though it is not certainly the equivalent of the Lake Superior sandstone east of Marquette. The Potsdam sandstone probably underlies the whole of the Michigan Basin. It outcrops at numerous points in the Northern Peninsula, especially along the Lake Superior shore from Marquette eastward to beyond Grand Portal, and it has been penetrated by drill holes in the southern part of the Peninsula. In the Southern Peninsula, it is so deeply buried that no borings have reached it. The formation is composed mainly of fragments of quartz and feldspar and comprises an upper red member, locally mottled and streaked, and a lower one of lighter color. It varies much in thickness, from 1500 feet at Grand Marais to only about 200 and 300 feet at Rapid River and on Neebish Island.

ORDOVICIAN.

Calciferos, Lower Magnesian, (Prairie du Chien), Hermansville Limestone. The Calciferous outcrops in the Northern Peninsula on Calciferous creek, a branch of the Au Train river, and on St. Mary's river near West Neebish Rapids. This formation, or perhaps only the lower part of it, is represented by the Hermansville limestone. It is mainly white sandstone, limestone, and sandy limestone. Its sandy phases resemble the St. Peters and the whiter portions of the Potsdam, hence the three formations are not readily separated in drill samples. Wells along Green Bay indicate a thickness of 200 to 250 feet.

St. Peters. Exposures of the St. Peters sandstone are not known in Michigan. Apparently it is about 75 feet thick at Marinette, (Wis.), absent near Stonington and 18 feet thick at Rapid River, but further east in the Northern Peninsula it has not been recognized. The formation is very irregular in thickness and appears to fill hollows in the eroded surface of the Calciferous. In the Southern Peninsula it has not been penetrated.

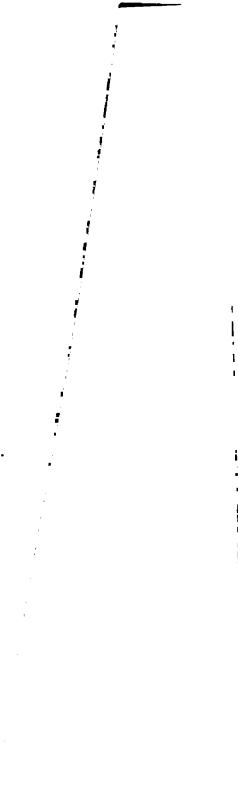
Trenton Limestone. The Trenton limestone outcrops at various places on the west side of Green Bay and Little Bay de Noc, along Rapid and Whitefish rivers, and on St. Marys river. Wells have penetrated it at Manistique, Pickford, on Manitoulin island, and in western Ontario. In the Southern Peninsula it has been penetrated only in the southeastern part and at depths of over 1500 feet. It is a widespread formation and probably once extended over the whole

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of Wisconsin and Michigan, but later was eroded from the present pre-Cambrian areas.

In the Northern Peninsula, it appears to be about 250 feet thick, though across the bay from Escanaba near Stonington it is over 270 feet thick. In the Southern Peninsula, its thickness is unknown.

In the Northern Peninsula the Trenton has three phases, (1) an upper granular, crystalline, dolomitic limestone of alternating blue and brown layers terminating at the base in a dark or black bituminous limestone, (2) a middle portion of cherty layers or lenses alternating with thick beds of limestone and, (3) a basal member of blue shales and limestone, a part of the latter being black or dark. The sandy middle division and the lower blue shaly one appear to have a widespread distribution.

The Trenton limestone is an important oil bearing formation in Ohio. In the outcrops near Rapid and Whitefish rivers in the Northern Peninsula, oil impregnates the rock and asphaltum gum fills the fissures and cavities. In Monroe county (Chapter IV) nearly all of the drill holes penetrating this horizon yield a little oil and gas. In Ontario, however, where it has been penetrated at many places, it is apparently barren.

Utica Shale. (Eden of Ohio). The Utica shale is very black and bituminous and of fairly uniform thickness which, however, varies from 50 feet in the Northern Peninsula to nearly 200 feet in the southeastern part of the Southern Peninsula. It is easily recognized, but drillers who are not familiar with it are apt to confuse it with the equally black Antrim shales of the Devonian.

Lorraine or Maysville. The Utica and Lorraine shales are soft rock, and therefore easily eroded. They occupy low ground extending through Green Bay and Little Bay de Noc and along the north side of the prominent escarpment of the Niagara limestone from Garden Peninsula to Drummond island. The Lorraine shale is generally calcareous and full of fossils. Its color is mainly blue but black streaks occur in it, especially towards its base. The top of the formation is hard to distinguish from the Richmond and the Medina shales above, and its base from the Utica shale below. According to Lane, in the southern part of the state there are above the Trenton about 600 feet of shaly beds of which he ascribes 200 feet to the Utica, 250 feet to the Lorraine, and 150 feet to the Richmond and Medina. In the northern part of the state the Lorraine is more variable in thickness, but it is apparently a very persistent formation throughout the State.

SILURIAN.

Richmond and Medina. These formations represent the transition from the blue shale of the Lorraine below to the red dolomitic beds

of the Clinton above. They are characterized by the prevalence of soft red shale, sandy in places and mixed here and there with green shale. The Richmond, Medina, and Lorraine cannot be sharply separated. The Richmond and Medina have not been recognized in outcrop anywhere in Michigan and apparently are only sparingly represented in the Northern Peninsula, but in southeastern Michigan and western Ontario, they are much more prominently represented. In Ontario the Medina is largely sandstone and an important oil and gas bearing formation with three productive horizons. In the Southern Peninsula, this formation is practically unexplored and little is known concerning its oil and gas possibilities.

Clinton. The Clinton formation is thin, poorly represented, and not readily separated from the Rochester shale above or the Medina below. In most places, where present at all, it is a clayey dolomite with more or less iron ore and red shale. Its thickness varies from nothing to 130 feet. The presence of water and gas is characteristic of the top of the formation.

Rochester Shale. A blue shale horizon which, though persistent, is never very thick (30 to 80 feet), occurs above the Clinton formation. In many places, it is absent. These blue shales have been correlated with the Rochester formation of New York but they may be a part of the Clinton.

The Niagara Limestone. (Guelph and Lockport.) In the Upper Peninsula, the Niagara limestone forms an almost continuous belt of outcrops from the southern part of Garden Peninsula along the Lake Michigan and Lake Huron shores to the eastern point of Drummond island. The formation is composed of an upper whiter part called the Guelph dolomite, and a lower less white and uniform one, the Lockport. This formation as a whole is remarkably free from impurities, especially iron and clayey material and is composed dominantly of carbonates of calcium and magnesium with the exception of thin lenses and nodules of chert and occasional sandy beds. Dolomite predominates, though there are heavy beds of very pure limestone in the lower part. According to Lane, the extreme whiteness of the upper part, its occasional grains of sand, and beds of sandstone and chert are characteristic throughout the State. Its thickness varies from 270 to 350 feet in the southern part of the Southern Peninsula to about 600 feet in the Northern Peninsula. The Niagara is an important producer of oil and gas in Ontario. The formation yields strong flows of fresh water or weak brine at one or more horizons. The mineralized waters or weak brines of the Niagara are characteristically different from the strong sulphate brines of the Monroe formation above.

Salina. The Salina in southeastern Michigan is an extremely variable formation composed of alternating layers of compact brown to drab dolomite, anhydrite (partially converted into gypsum), and salt beds with minor amounts of red, green, and rarely blue and black shales, and dolomitic marls or oozes. It cannot always be separated from the overlying Monroe Formation, because the salt beds are absent in many areas and there is nothing to distinguish the dolomites of the Salina from those of the Monroe. In the absence of salt beds, the top of the first gypsum bed may be taken as the dividing line but as there is more or less gypsum in the Lower Monroe, and even in the Upper Monroe, this is an unsatisfactory basis of division. In the Northern Peninsula and in southwestern Michigan, the Monroe and Salina cannot be differentiated.

In southeastern Michigan and western Ontario, the thickness of the Salina ranges from 370 feet to more than 950 feet, but the average for the Detroit river district is 700 to 800 feet. Rock salt beds have a great development along the flanks of the Cincinnati anticline and, in Michigan, the aggregate thickness of the beds increases down the dip to the northwest, the total thickness being over 609 feet in the Royal Oak well in Oakland county.

South of a line from Muskegon through Kalamazoo to Trenton, no rock salt has been found. In the southwestern and western part of the State, the Salina is much thinner and cannot be separated from the Monroe beds above it. In the Manistee Ludington salt district, the salt beds have an aggregate thickness of only 20 to 40 feet. In Presque Isle and Alpena counties, the Salina apparently is developed to an equal or even greater thickness than in southeastern Michigan. The Salina is apparently over 1100 feet thick in the Onaway well where it includes over 800 feet of rock salt. The Grand Lake well penetrated 428 feet of the Salina, including nearly 325 feet of salt, but did not reach the bottom of the formation. Further drilling may show that the Manistee-Ludington, Alpena-Onaway, and the southeastern Michigan and western Ontario rock salt areas are only portions of a large area.

Signs of oil and gas have been observed in the lower dolomite of the Salina, but in southeastern Michigan this formation has been penetrated at so many places without striking any noteworthy amounts of either oil or gas (aside from hydrogen sulphide gas) that it does not appear to be a promising oil and gas bearing formation.

Monroe Formation. The Monroe formation is divided into three parts—Upper, Middle (Sylvania), and Lower, but these divisions can be clearly recognized only in southeastern Michigan.

Lower Monroe or Bass Island Series. The Lower Monroe, or Bass

Island Series, is exposed in eastern Monroe county. It varies from about 365 feet to 440 feet in thickness in southeastern Michigan. Oolite, sandy dolomite, dolomite with anhydrite, and acicular or gashed dolomite are characteristic of the formation in both the Northern and the Southern Peninsulas.

Sylvania. Middle Monroe. In southeastern Michigan the Sylvania sandstone is composed of very white sandstone, (5 to 300 feet thick) and of siliceous limestone or dolomite (30 to 165 feet). This formation is found only along the flanks of the Cincinnati anticline. It is thicker along a line from Milan, Monroe county, northeast to Royal Oak, Oakland county. To the west of this line and also toward the outcrop, where it is between 50 and 100 feet thick, the formation grows thinner. Toward the north, along St. Clair river it grades into sandy dolomite. The Sylvania sandstone is very easily recognized for it is pure white, generally incoherent or little cemented, and resembles granulated sugar. It yields "sulphur" water and much hydrogen sulphide gas.

Upper Monroe or Detroit River Series. The Upper Monroe (0—350 ft.) is composed mainly of dolomite interstratified with limestone of great purity, the Anderdon beds. One of the heavy beds of dolomite is bituminous and oily throughout, and oil occurs also in cavities and fissures in this formation. Little or no free oil has been found, however, in the many drill holes which have penetrated this formation along Detroit and St. Clair rivers.

DEVONIAN.

Dundee (Corniferous) limestone. The Dundee limestone underlies most of the Southern Peninsula, and, under other names, western Ontario, and the Ohio and the Mississippi valleys. Its exposures skirt the northern shore of the Lower Peninsula from the northwestern point of Emmet county to the eastern extremity of Presque Isle county, and extend from southeastern Wayne county southwest through Monroe and Lenawee county into Ohio. It has been penetrated in hundreds of drill holes in the Southern Peninsula and Ontario. It is the lowermost formation which has been penetrated in the central part of the Southern Peninsula, having been encountered at depths ranging from 2900 feet at Saginaw and 3270 feet at Bay City to 3667 feet at Mt. Pleasant.

In southeastern Michigan, the Dundee is only about 100 feet thick, but it gradually thickens west and northwest to a maximum of 250 feet throughout an area extending northeast from Barry, Eaton, and Jackson counties into Saginaw and Bay counties. In the southwestern part of the Southern Peninsula, and especially in the western part, it

becomes much thinner. At Allegan it is not over 125 feet thick, perhaps absent at Muskegon, and is only 100 feet thick at Ludington. In Presque Isle and northern Alpena counties, however, the thickness is over 200 feet thick.

In Michigan, the Dundee nearly everywhere is a true limestone, usually light gray to buff in color, very fossiliferous, and locally containing nodules and seams of chert. Some of the beds of limestone are remarkably pure, averaging over 98 per cent calcium carbonate. With dilute acid, the Dundee limestone always gives a vigorous effervescence in marked contrast to the Monroe dolomite below. The formation² in many places gives off a strong odor of oil and contains drops of thick black bituminous matter in small cavities. In Ontario, the formation yields oil in considerable quantity, but in Michigan, at Port Huron, Saginaw, and Allegan, it scarcely approaches commercial importance as an oil producer. From the fact that the Dundee usually shows abundant signs of oil and gas wherever penetrated, and that it is easily accessible nearly everywhere in the Southern Peninsula, it appears to be the most promising oil formation of the State.

The Dundee generally yields an abundance of sulphate water or strongly mineralized brines at some distance from the top. So much water was encountered in the top of the formation in the Braun well at Mt. Pleasant as to cause its abandonment.

Traverse (Hamilton and Marcellus) Formation. The Traverse formation outcrops along the south side of Little Traverse Bay and at various points across the northern end of the Southern Peninsula into Presque Isle and Alpena counties where it is extensively exposed or is under light drift cover. In southeastern Michigan, it is wholly concealed by drift. The formation is essentially a series of transition limestones, generally hard and fossiliferous, and calcareous shales or soapstones from the Dundee limestones below to the heavy shale of the Antrim above. Wells along Little Traverse Bay indicate that limestone greatly predominates over the shale in that portion of the Southern Peninsula. Some of the limestones are very high grade and are quarried on an extensive scale in Alpena, Charlevoix and Emmet counties. In the northern and eastern parts of the Southern Peninsula, the formation averages about 600 feet thick. In the southern and southeastern parts it is much thinner, being only about 300 feet at Port Huron, 168 feet at Milan, less than 100 feet at Adrian, 55 feet at Jackson and Charlotte, 70 feet at Kalamazoo, and 190 feet at Benton Harbor. A heavy blue or black shale, the Bell (or Marcellus) occurs nearly everywhere at the base and is thus of great stratigraphic importance.

²Sherzer: *Geology of Wayne county*, Pub. 12, Geol. Series 1, p. 201, Michigan Geological and Biological Survey.

In the recent drill holes (see Chapter VI) in the vicinity of Saginaw, an excellent oil was found in a sandy or cherty limestone at the top of the Traverse, but not in commercially important quantities. In one of the wells, three oil bearing horizons were encountered in the Traverse. The oils from the lower horizons were black, much heavier, and of inferior grade. Elsewhere in the State the Traverse has given little promise.

Antrim Shale. (Ohio, Huron, Chagrin, Cleveland, and Bedford of Ohio, Genesee, Portage, and Chemung? of New York). The Antrim black shale is one of the most easily recognized horizons in the Southern Peninsula. It varies from 140 to 480 or more feet in thickness and consists mainly of pyritic shales, nearly everywhere black and bituminous in the lower part and locally blue in the upper part. Spherical to ellipsoidal calcareous concretions from an inch to six feet in diameter are characteristic of the formation in certain localities. Where the Antrim passes into the Berea horizon, elsewhere represented by sandstone, it is generally red, gritty, or interstratified with thin sandstone lenses. In places this formation contains so much bituminous matter that it resembles coal and can be burned. Generally it smells strongly of petroleum and nearly always yields small quantities of gas when penetrated in drill holes. The oil and gas of the Upper Traverse and of the Berea sandstone were possibly largely derived from this bituminous shale. The Devonian formations, especially the Antrim and Dundee, can be traced across southeastern Michigan by a line of "shale" or surface gas wells and gas springs.

MISSISSIPPIAN.

Berea Sandstone. This formation was originally defined by Lane³ as the Richmondville sandstone and was regarded as equivalent of the Berea grit of Ohio. Later he concluded that the "Richmondville" is not the exact equivalent of the Berea, "but a stray sandstone higher up." The Berea in Michigan forms the base of the Coldwater, but it cannot always be recognized with certainty on account of the occurrence of sandstone in the lower portion of the Coldwater.

The Berea exists as a sandstone only on the eastern side of the Southern Peninsula, where it is generally white to gray in color and full of pure strong salt brine. In southeastern Michigan, it is a coarse gray sandstone, 100 feet or more in thickness, but, in Saginaw Valley, it is generally very fine grained. Farther north in Iosco and Alcona counties, the Berea is much thinner, and, towards the western side of the State, the formation disappears as a sandstone. At Alma, Mt.

³Sherzer: Geology of Wayne county, Pub. 12, Geol. Ser. 9, 1911, p. 191.

Pleasant, and Grayling, it is either represented by red shales, locally sandy, or it is absent.

At Blackmar, Saginaw county, Bay City, and Killmaster, Alcona county, this formation yields very considerable quantities of gas, and, previous to the recent explorations at Saginaw, it was supposed to be one of the most promising gas horizons in Saginaw Valley. Unfortunately, it proved to be so fine grained that it yielded relatively little brine, and only moderate amounts of gas. On the western side of the State, owing to the red shaly character of the rock of the Berea horizon, the possibilities seem to be less promising than on the eastern side.

Coldwater Shale. Part of Waverly, Sunbury or Berea shale together with Cuyahoga and Raccoon(?) and perhaps Black Hand of Ohio. The Coldwater shale is one of the thickest formations in the State. It underlies the surface deposits of a large portion of the Southern Peninsula, but, being a soft formation, has but few exposures. It is composed largely of blue shales with nodules of iron carbonate, especially near the top, and lenses of sandstone and sandy shale with subordinate streaks of limestone, particularly on the western side of the State. A thin, but very persistent black bituminous shale, called the Sunbury or Berea, lies at the base just over the Berea grit. At the top, the Coldwater grades upward into the red shale and sandstone of the Lower Marshall, from which it cannot be sharply separated. The Coldwater and the Lower Marshall are apparently from 1000 to 1200 feet or more in thickness. The shales are soft, nearly everywhere free from water, and afford the easiest of drilling. In some places brine bearing sandstone lenses occur at some distance above the Berea grit and cannot readily be distinguished from it, as in the Bay City, Grand Rapids, Caseville, Tawas City, and Richmondville wells.

Marshall Sandstone. *Napoleon* or *Upper Marshall* and *Lower Marshall*. (Raccoon, possibly, Black Hand and Logan of Ohio in part, Kinderhook of Illinois.) The Marshall sandstone forms an almost continuous belt around the central portion of the Southern Peninsula and outcrops at many points throughout an arcuate belt from Port Huron southwest into Jackson, Hillsdale, and Calhoun counties and thence northwestward into Ottawa county. It consists of an upper coarse white to gray pyritous and nonfossiliferous sandstone, called the Napoleon sandstone, and a lower white to gray or red micaceous sandstone grading downward into sandy red and blue shales. In Huron county the Lower Marshall is largely sandstone and contains minor amounts of "peanut" conglomerate, composed of rounded fragments of quartz, which resemble peanuts, and grindstones and whetstones. In the central part of the Michigan Basin, the sand-

stone of the Lower Marshall is replaced by a series of red and blue shales, usually sandy. The bottom, and especially the top, is generally marked by a red sandstone or sandy shale popularly called, "paint rock."

The Upper Marshall is nearly nonfossiliferous but the Lower Marshall has several extremely fossiliferous horizons. Strong brine occurs in abundance in the Upper Marshall away from the outcrop and is characterized by its content of bromine, especially toward the centre of the Basin. Near the margin, the Napoleon is an abundant source of fresh water. The thickness of the Marshall formation in Huron county is fully 560 feet, but elsewhere in the State it varies from 260 to 300 feet. Hundreds of drillings for oil, brine, or fresh water have penetrated the Marshall but no signs of either oil or gas have been encountered anywhere.

Michigan Series or Lower Grand Rapids. The Michigan Series is a variable formation both in thickness and character. It consists chiefly of dark or bluish limestone or dolomite with blue or black, and, rarely, reddish or greenish shales and dark or red sandstone. Well records indicate that gypsum or anhydrite, associated with dark dolomite and dark blue shale, occurs everywhere near the middle of the formation. In certain areas, gypsum beds are numerous, but most of them are thin, ranging from a fraction of an inch to a foot or more thick. Some of the thicker beds which are being quarried and mined in Kent and Iosco counties, however, are from 6 to 23 feet thick. The sandstones are thin and irregular, and dark limestones occur near the base of the formation.

Near the margin, excepting along the southeastern portion, the formation is apparently about 200 feet in thickness, but toward the center of the Basin it is much thicker, being 330 feet at Midland and 358 feet at Mt. Pleasant. Along the southeastern margin from Tuscola county into Jackson county the formation is absent in whole or in part. The water from the Michigan Series is salty and "bitter," being high in sulphates of calcium and magnesium. The high content of sulphates in these brines readily distinguishes them from those of the Marshall immediately below.

Bay Port Limestone or Maxville. *Upper Grand Rapids*, (Upper St. Louis, Middle Kaskaskia.) The Bay Port, or Maxville, limestone is very irregular in thickness and distribution owing to heavy erosion subsequent to its deposition. The unconformity between the overlying Coal Measures and the Maxville is very pronounced and distinctly marks the division between the Mississippian and Pennsylvanian. Present evidence afforded by drillings and rock exposures indicates that the Maxville exists only

in fragments over much of the Basin. On the southeastern margin from Tuscola into Livingston county, it seems either to have been completely removed by erosion or was never deposited. From Jackson to Grand Rapids, remnants of the Maxville occur and this evidence points to the probability that erosion rather than non-deposition explains the apparent absence of the formation along the southeastern margin. Generally, the formation is not over 50 to 75 feet in thickness, but at Mt. Pleasant it appears to be 235 feet thick. Hard light bluish limestone with chert and white sandstone lenses are characteristic.

PENNSYLVANIAN.

Parma Sandstone or Conglomerate. (Pottsville). The Parma is a white sandstone containing local conglomerates with small white quartz pebbles like split peas. It is the basal member of the Pennsylvanian and a very persistent and easily recognized horizon varying from 0 to 170 feet in thickness. It yields an abundance of fresh water around the margin and sulphate brines near the center of the Basin.

Saginaw Formation (Upper Pottsville). The Saginaw formation is the uppermost and youngest of the Paleozoic sediments and underlies the drift in the whole central portion of the Southern Peninsula. Unlike the lower formations, it does not partake of the basin-like structure; its strata, aside from local undulations and small folds, are practically horizontal. The Saginaw formation averages about 400 feet in thickness, and is composed of white shales or so-called fire clays, sandstones, black shales, and coal seams. There are also subordinate amounts of blue shales, thin seams of black band ore (siderite) and, rarely, beds of thin limestone. In general, the strata vary markedly in character and thickness within relatively short distances. Apparently, however, there is a curious persistence of local facies; that is, in one locality the strata may be predominantly sandstone, while in another shales predominate. The same is true of the coal seams, some regions having several seams, generally thin, and other regions none.

Near Fowlerville, a little oil was struck in a sandy shale in the top of the formation. Many drill holes have penetrated this formation and the underlying ones down to the Upper Marshall or Napoleon without striking any noteworthy signs of oil or gas.

POSSIBLY PERMO-CARBONIFEROUS.

Woodville. (Conemaugh?). Near Jackson, at Woodville, there is a sandstone 79 feet thick, which Winchell separated from the Coal

Measures and called Woodville. Wells at Maple Rapids, St. Johns, Ionia and Gladwin indicate the presence of a reddish sandstone which may be the same as the buff colored Woodville. Being at the top of the Coal Measures, the sandstone apparently has been largely removed by erosion.

PLEISTOCENE.

Nearly the whole state is covered with drift or glacial deposits of sand, gravel and clay varying from a thin veneer to 1000 feet or more in thickness. In most of the eastern half of the Northern Peninsula and in the southern half of the Southern Peninsula the drift is generally less than 200 feet thick, and does not commonly exceed 300 feet, but throughout a broad belt extending from Mason, Oceana, and Newaygo counties northeastward into Otsego, Montmorency, and Alcona counties, the depth to rock varies from 300 to 1000 feet or over and the average depth is probably nearly if not fully 600 feet. From the head of Saginaw Bay southwest to Alma, and thence northwest through Mason and Manistee counties to Lake Michigan, there is an old pre-glacial rock valley in which the drift is also very deep, especially toward the west, being 400 to 500 feet in Isabella county and 500 to over 700 feet in Manistee county. In Presque Isle and Alpena counties, in eastern Monroe county, and in Hillsdale, Calhoun and Jackson counties the drift is absent, or thin, over areas of considerable extent. In the eastern half of the Northern Peninsula a broad belt along the shores of Lake Michigan and Lake Huron from Little Bay de Noc eastward to Drummond Island, and another north from Little Bay de Noc to Lake Superior are thinly drift covered. Locally, near the lake shore in the Southern Peninsula and around the margin of the Coal Basin, rock is exposed, or but thinly covered with drift.

Nearly everywhere the drift contains thick beds of sand and gravel full of water. Where such beds have a suitable cover of clay and overlie the Devonian formations, especially the Antrim or Dundee, they yield small to considerable quantities of gas. From St. Clair county southwest to Ohio, this surface or "shale" gas has been utilized by the farmers for domestic purposes. In the northern part of the Southern Peninsula, where the drift is locally very thick over the Antrim shale, considerable bodies of gas are liable to be encountered in gravel beds. At a depth of about 425 feet, a strong flow of gas with a pressure of about 190 pounds was struck in the drift at Onekama, (Chap. VIII), Manistee county.

CHAPTER II.

GEOLOGICAL FACTORS CONTROLLING THE OCCURRENCE
OF OIL AND GAS.

THE ANTICLINAL THEORY.

Very soon after the development of the great oil fields of the country, it was independently observed by different investigators, and by some of the practical oil and gas operators, that the great oil and gas wells in Pennsylvania, Ohio, and West Virginia, were aligned along the crests of anticlines. T. Sterry Hunt¹ was one of the first to recognize the influence of anticlinal folds, in the accumulation of oil in Ontario, and asserted that such structures are absolutely necessary for large accumulations. E. B. Andrews² independently reached a similar conclusion in studying the oil and gas wells of the White Oak anticline in the vicinity of Burning Springs, West Virginia, and explained the separation of gas, oil, and water as due to gravity. In a series of articles in 1881, F. W. Minshall of Ohio advocated views similar to those of Andrews concerning the West Virginia "Oil Break." H. Hoefer of Austria, without knowledge of Hunt's and Andrews' publications, recognized that "rock disturbance" is a fundamental factor in the accumulation of oil and gas in Pennsylvania and, in 1876, published the elements of the anticlinal theory in a book "The Petroleum Industry of the United States."

While the influence of the anticlinal structure was early recognized, no attempt was made to use it in a practical way until 1883, when I. C. White of West Virginia in connection with Wm. A. Earseman, a practical oil operator, made an exhaustive study of the gas fields in the Appalachian district and reached the conclusion that "rock disturbance caused by anticlinal waves" is the important factor in the occurrence of both oil and gas. Working upon this hypothesis, the Grapeville, Washington, and other great gas pools were located in the next two years. In 1885, the theory was published by Dr. White³ in *Science*, and the essentials of the theory, as first stated by him in connection with the accumulation of gas, is best given in the following paragraphs from this article.

¹Canadian Naturalist, 1859. Amer. Jour. Sci., Mar. 1863.

²Amer. Jour. Sci., May 1861.

³Science, June and July, 1885. The Geology of Natural Gas. See also reprint, Geological Survey, West Virginia, Vol. 1, 1899, pages 160-175.

"The first explorers assumed that gas could be obtained at one point as well as at another, provided the earth be penetrated to a depth sufficiently great; and it has required the expenditure of several hundred thousand dollars in useless drilling to convince capitalists of this fallacy, which even yet obtains general credence among those not interested in successful gas companies.

"The writer's study of this subject began in June, 1883, when he was employed by Pittsburg parties to make a general investigation of the natural gas question with the special object of determining whether or not it was possible to predict the presence or absence of gas from geological structure. In the prosecution of this work, I was aided by a suggestion from Mr. William A. Earseman, of Allegheny, Pennsylvania, an oil operator of many years experience, who had noticed that the principal gas wells then known in western Pennsylvania were situated close to where anticlinal axes were drawn on the geological maps. From this, he inferred there must be some connection between the gas wells and the anticlines. After visiting all the great gas wells that had been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated either directly on or near the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further observation showed that the gas wells were confined to a narrow belt, only one-fourth to one mile wide, along the crests of the anticlinal folds. These facts seem to connect gas territory unmistakably with the disturbance in the rocks caused by their upheaval into arches, but the crucial test was yet to be made in the actual location of good gas territory on this theory. During the last two years I have submitted it to all manner of tests, both in locating and condemning gas territory, and the general result has been to confirm the anticlinal theory beyond a reasonable doubt.

"But while we can state with confidence that all great gas wells are found on the anticlinal axis, the converse of this is not true, viz., that great gas wells may be found on all anticlinals. In a theory of this kind, the limitations become quite as important as, or even more so than the theory itself; and hence I have given considerable thought to this side of the question, having formulated them into three or four general rules (which include practically all the limitations known to me, up to the present time, that should be placed on the statement that large gas wells may be obtained on anticlinal folds), viz.:

(a) "The arch in the rocks must be one of considerable magnitude.

(b) "A coarse or porous sandstone of considerable thickness, or, if a fine grained rock, one that would have extensive fissures, and thus in either case rendered capable of acting as a reservoir for gas, must underlie the surface at a depth of several hundred feet (500 to 2,500).

(c) "Probably very few or none of the grand arches along the mountain ranges will be found holding gas in large quantity, since in such cases the disturbance of the stratification has been so profound that all the natural gas generated in the past would long ago have escaped into the air through fissures that traverse all the beds.

(d) "Another limitation might possibly be added, which would confine the areas where great gas flows may be obtained to those underlain by a considerable thickness of bituminous shale.

(e) "Very fair gas wells may also be obtained for a considerable distance down the slopes from the crests of the anticlinals provided the dip be sufficiently rapid, and especially if it be irregular or interrupted with slight crumples. And even in regions where there are no well marked anticlinals, if the dip be somewhat rapid and irregular, rather large gas wells may occasionally be found, if all other conditions are favorable.

"The reason why natural gas should collect under the arches of the rocks is sufficiently plain from a consideration of its volatile nature. Then, too, the extensive fissuring of the rock, which appears necessary to form a capacious reservoir for a large gas well, would take place most readily along the anticlinals where the tension in bending would be greatest."

The theory was from the first enthusiastically accepted by many as a complete explanation of both oil and gas accumulations, but was violently attacked and opposed by others. There was such a general attempt on the part of the champions of the theory to explain all accumulations on the anticlinal basis without due regard to White's "limitations" and to other limiting factors not then known or fully recognized that the theory suffered more or less unjust criticism. C. Ashburner, geologist in charge of the Second Pennsylvania Survey, who was a strong opponent of the theory held that the relation between gas wells and anticlinals was merely one of coincidence, and also that large gas wells could be found in synclines. Dr. White's answer to these criticisms is given in the following extract from an article published in *Science* July 17, 1885.

"In reply to Mr. Ashburner's criticism of the views advanced in my article on natural gas, I would say that the necessary brevity of the paper in question prevented the mention of many facts that might have rendered the conclusions clearer and less open to challenge. One

of these is that my communication had especial reference to the natural gas regions proper, i. e., where the gas is unconnected with the oil fields. Most geologists know that natural gas in large quantities exists with and contiguous to every oil pool, apparently as a by-product in the generation of the oil, and of course the rocks are filled with it wherever it can find a reservoir. To gas wells from such sources Mr. Ashburner's criticism may sometimes be found applicable; but, even with these, by far the larger ones will be found on the arches of the rocks.

"The cases that Mr. Ashburner mentions, where large gas wells have been found at the centers of synclines, do not necessarily contradict my conclusions; for no one knows better than he that a subordinate crumple or anticlinal roll often runs along the central line of a syncline.

"My excuse for writing the article on natural gas was that I might be of some service in preventing the waste of capital that has been going on within a radius of fifty miles of Pittsburg by an indiscriminate search for natural gas; and it is a sufficient answer to Mr. Ashburner's criticism to point him to the brilliant lights along the crests of the Waynesburg, Pinhook, Washington, Bull Creek, Bradys Bend, Hickory, Wellsburg, Raccoon, and other anticlinals, and also the darkness that envelops the intervening synclines, in which hundreds of thousands of dollars have been invested without developing a single profitable gas well. The same results has been proven in other portions of the country. The Great Kanawha Valley above Charleston has been honeycombed with borings for salt, and the only gas wells developed were found within a belt a few rods wide, which coincides with the crest of the Brownstown anticlinal, where immense flows were struck. In this connection, I should say that Col Allen, of Charlestown, says he can trace the Brownstown anticlinal by the escaping gas across streams and even mountains, from the Kanawha river to the Big Sandy, where, on its crest, near Warfield, two of the largest gas wells ever known have recently been struck. At Burning Springs, on the Little Kanawha, the only large gas wells were found on the very crest of the great uplift in that region. The gas belt of western Ohio, through Findlay and other towns, follows closely the line of the Cincinnati arch, and the same story is repeated in other localities too numerous to mention.

"Mr. Ashburner can, if he chooses, interpret these facts as mere coincidences, and explain them to himself as having no more bearing on the question of finding gas than "Angell's belt theory" of oil; but the practical gas operator can no longer be deluded by such logic into

risking his money in water holes (synclines) where so many thousands have been hopelessly squandered.

"With regard to the anticlinal theory not being a practical basis for successful operations, I deem it a sufficient reply to state that all the successful gas companies of Western Pennsylvania and West Virginia are getting their gas from the crests of anticlinal axes, while those that have confined their operations to synclines have met with uniform financial disaster.

"The statement was distinctly made in my original communication that gas would not be found on all anticlinals, nor at all localities along one that actually produces gas, since other factors have to be considered, as there stated; but, with the facts before us, it would certainly prove a great saving of capital in the search for gas if operations were confined to the crests of anticlinals, and I fail to perceive how Mr. Ashburner's fears for the 'misleading' character of my article can be realized."

In the March number of the *Petroleum Age* in 1886, Dr. White, in reply to further criticism by Mr. Ashburner, published another paper on the occurrence of gas particularly in western Pennsylvania. In this paper he recognized the importance of the "crowns," "hogbacks," or domes formed through the intersection of the main anticlines by minor ones, in causing local concentration of the oil and gas at these points. These localizations at the cross arches explain why the course of some anticlines are marked by a *line of groups* of productive wells with barren or "lean" territory in the sags or "saddles" between the "crowns" or domes.

"An inspection of the accompanying map will reveal the fact that the main northeast and southwest anticlinals are cut by another set at nearly right angles, which have been termed crosscut anticlinals.

"The principal anticlinal axis of Illinois puts out in Ogle county, in the northern part of the state, and extends in a direction S. 20° E. . . . Along this axis natural gas can be traced in springs and well borings for a distance of 160 miles. *It is however, more prevalent on the crowns of the cross axes.*

"This same story is repeated in Ohio according to the testimony of the eminent state geologist, Professor Orton.

"These cross-cut arches result in carrying the anticlinal structure and a line of disturbance in the rocks directly across the trend of a syncline, and failure to grasp this fact is the principal reason why Mr. Ashburner insists upon his readers believing that a great gas well may be obtained in a syncline; for it is quite certain that no large gas well has ever yet been found in the trend of a syncline, except where

the trough itself has been elevated by a long rise which is of course brought about by the crosscut folds.

"These are the geological surroundings of all those wells which Mr. Ashburner cites from northern Pennsylvania and southern New York as occurring in synclines. It is not necessary to show a reversed dip..... in order to demonstrate the existence of one of those crosscut waves, since their crests are often marked by a simple flattening of the rate of dip along the latter. Professor Orton would call such a structure (where there is no reversal of dip, but only a change in rate) a suppressed anticlinal, a very good name, for such it really is.

"It follows, of course, that a synclinal structure may be converted into an anticlinal one by the presence of the crosscut wave, so the reverse may and frequently does happen."

As noted in the foregoing paragraphs, the theory was stated with special reference to the accumulations of gas and the "limitations" given by White were not intended to cover occurrences of oil, or of gas in association with oil.

E. Orton⁴ grasped the truth of the principles of the anticlinal theory and used them to explain the accumulations of oil and gas in Ohio where pronounced anticlinals are few, or wanting in many areas. He held that structure is a vital element in the accumulation of either oil or gas and recognized clearly that the principles of the anticlinal theory applied to *any structure* having an anticlinal effect, provided that due regard be given to the "limitations" of the theory, i. e., to the other geologic factors such as water, porosity, size of the pores, and source of hydrocarbons. In brief, he asserted that in a wide area where the rocks are nearly horizontal no marked accumulation can take place until the rocks are tilted considerably so that the small disseminated particles of oil, gas, and water found in nearly all sedimentary rocks can rearrange themselves in the rocks in the order of their specific gravities, assuming the presence of water, a suitable reservoir and an impervious cover to retain the petroliferous products. The gas being lightest is found at the top, the oil next below and the water lowest, filling the rest of the rock reservoir. The ideal conditions for an anticlinal structure are illustrated by figure 4.

The principles of the theory have been widely accepted and applied in the practical development of oil and gas fields in general. Unfortunately at first, the importance of the "limitations" were often ignored, but costly experience has demonstrated the truth of White's statement that they are of as much or even greater importance than the theory itself. Under the anticlinal theory as later developed by

⁴Ohio Geol. Survey, Vol. VI, pp. 89-96.

White, Orton and others, oil and gas may be expected to occur most abundantly on or near the crests of anticlines or *other rock structures*, anticlinal in effect, provided: (1) that a suitable reservoir is present, (2) that the rocks are saturated with water, and (3) that there is an impervious cover over the reservoirs. Orton asserted that the three limiting conditions are more often met together than structure alone, but that they can not produce an accumulation without the aid of a proper structure. Evidently, a large accumulation can not occur without the presence of a stratum not only with a large amount of pore space but also with pores of sufficient size to permit the ready passage of oil and gas in response to gravity or hydrostatic force, nor is oil likely to occur near the crests of anticlines or structures of like

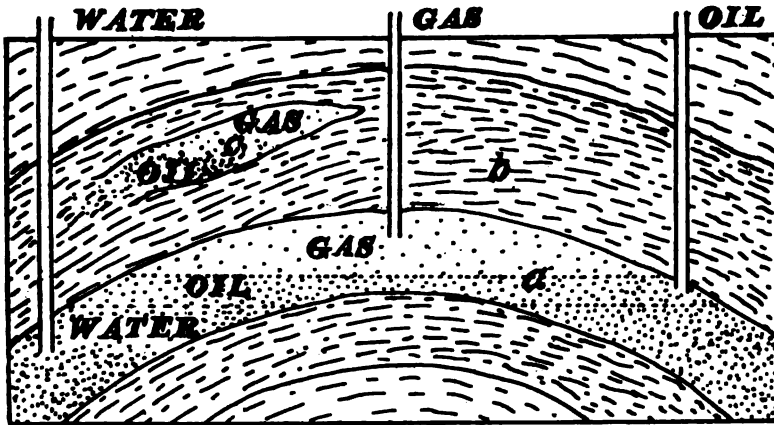


Figure 4. Ideal relations of oil, gas, and water in reservoirs. (a). Sandstone bed interstratified with impervious beds. (c). Sandstone lens wholly sealed in by shales b and not in communication with water.

effect without the rocks are saturated with water which tends to float the oil upward to the highest possible points.

In Pennsylvania and West Virginia, the regional folding has produced a series of pronounced anticlinal and synclinal folds with minor folds, superimposed on the larger ones, all extending in a general north-east southwest direction. As noted on previous pages, the location of all the great gas wells in the latter state, on or near the crests of the pronounced anticlines, was the significant fact which gave rise to the anticlinal theory as stated by White. Since the axes of anticlines do not usually lie in a horizontal position but undulate more or less, resulting in an alternating series of rises or domes and sags, the greatest accumulations generally occur near the crests of the domes while little or no oil and gas is found in the sags, as noted by Orton and White. In many cases, however, considerable bodies of oil and gas

but it is so broad and flat that it partakes little of the nature of ordinary anticlines. On the eastern flank of this structure, however, there are a few minor anticlines related in part to the "anticlinal waves" of western Pennsylvania and West Virginia, but, in general, the disturbing force in eastern Ohio produced only marked irregularities in the normal dip. Orton noticed that in many oil and gas fields of Ohio, where anticlines are absent, that the general dip becomes flatter, or even horizontal over a considerable area before the normal dip is again resumed. This gives rise to a structural "bench" or terrace or the *arrested* anticline of Orton. In such cases, the upward migration of the oil and gas is arrested or retarded by the flatter dip, and accumulation occurs beneath the terrace and on the lower slope.

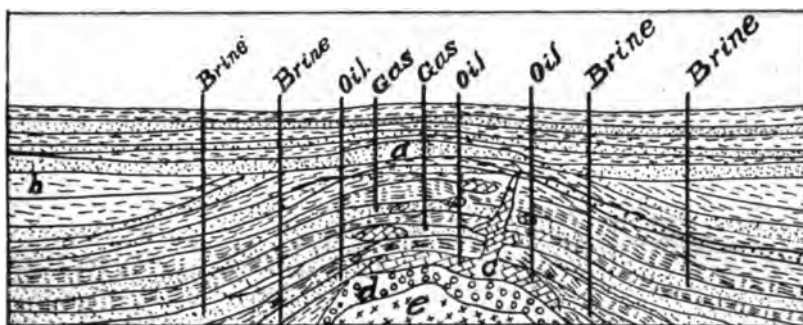


Figure 6. Cross section of the saline dome of the Spindle Top oil field, Texas. (After Jaeger).

- (a). Unconsolidated sands and gravels. Great gas reservoirs just above the limestone.
- (b). Clays, often of the "gumbo" character.
- (c). Cavernous limestone, the chief oil reservoir.
- (d). Gypsum.
- (e). Rock salt.

This appears to be the case at Alleghan where the dip of the strata suddenly changes. (See Fig. 13).

In Texas and Louisiana, the rock strata are locally arched up into domes or quaquaversal anticlines, which appear to be due to dynamic force resulting from the deposition of rock salt and gypsum from ascending waters. These substances always form the inner core of the domes. (See Fig. 6). The greater part of the oil and gas found in such structures occurs in the porous limestone, which forms the capping over the salt, or in porous strata immediately above the limestone. Spindletop is one of the most noted of these oil and gas structures.

While stringers of salt ramify the dolomites for a short distance above the salt beds in Michigan, there is no evidence that the strata have been arched up into domes as in Texas and Louisiana.

In California, Oklahoma and Pennsylvania and other states many

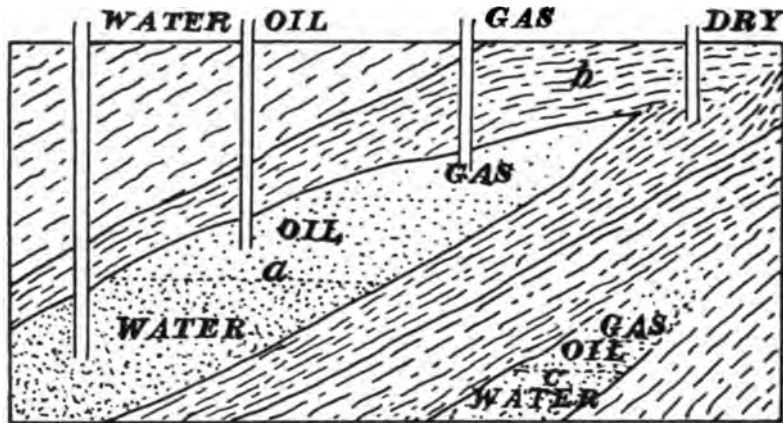


Figure 7. Forms of oil and gas reservoirs.
 (a). Inclined lens of sandstone sealed in by shales (b) but somewhere in communication with water under hydrostatic pressure.
 (c). Inclined bed of sandstone grading into shales and sealed in by them, but somewhere in connection with water as in (a).

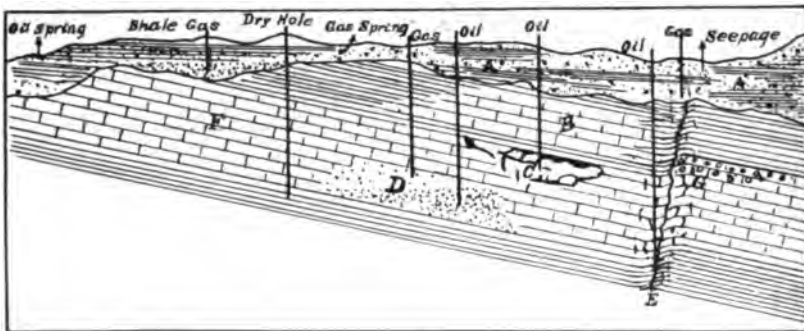


Figure 8. Sketch showing forms of oil reservoirs.
 A. Surface sands and clays.
 B. Limestone lens in shale.
 C. Fissured or cavernous limestone.
 D. Sandstone lens in limestone.
 E. Fault with fractured or brecciated zone in the limestone, but more or less sealed in the shale.
 F. Oil bearing limestone formation.
 G. Porous area containing oil and gas not in communication with water.

accumulations of oil and gas occur on unbroken slopes, apparently not related to structure but drillings have shown that generally the accumulations in such cases are contained in porous strata grading up the dip into impervious rock. (Fig. 7). In many instances, the oil reservoir is a porous sandstone lens (c of Fig. 4) hermetically sealed in by impervious shale, in other cases a porous limestone (Fig. 8) surrounded by less porous rock. In the same regions, however, many

of the accumulations and, generally the more important ones, are determined by the anticlines and terraces.

A less common structure is that produced by an unconformity, especially an angular unconformity. In the Coalinga⁶ district of California, the oil migrates up the highly inclined strata of the petroli-ferous Tejon shales into the flat unconformable Vaquereros sandstone above and collects in certain favorable places forming the chief oil accumulations of the district. Similar conditions are illustrated in (Fig. 19), which shows the edge of the inclined Berea sandstone in Alcona county unconformably overlain by the Pleistocene deposits. As shale gas is abundant in the drift along the strike of the oil and gas formations in Michigan, it is proof beyond reasonable doubt that the gas has escaped from the underlying rocks into the overlying sand and gravel beds, as at Killmaster (See Chapter IX), Alcona county.

In eastern Mexico, the accumulations are in the upturned edges of porous strata adjacent to old volcanic necks. This form of occurrence is one of the strongest arguments advanced by the exponents of the inorganic theory of the origin of oil. The oil, however, instead of originating from volcanic emanations from the interior of the earth much more plausibly has been distilled by volcanic heat from the bituminous matter in the intruded sedimentary strata.

In many oil fields, particularly those of the western states, there are numerous faults involving weak or soft strata such as clays and shales. Fractures and faults in such formations are readily healed, preventing the escape of oil and gas from the porous reservoirs below and these products may collect next the ends of the impervious strata, as illustrated in Figure 8. In some oil and gas fields, as in the Niagara limestone of western Ontario, fissured and fractured zones in dense non-porous limestones form the chief oil reservoirs. (Fig. 8). Since the Niagara yields oil only a few miles east of Detroit river, and as the strata are locally disturbed along the river, it is possible that similar fractured zones may exist in the Niagara in southeastern Michigan and prove oil bearing.

From a study of the occurrence of oil and gas in the various fields of the United States, Canada, and Mexico, the following generalizations may be made concerning the application of the anticlinal theory.

1. With a completely saturated oil stratum, the accumulations show a definite relation to the geologic structure.
2. In general, the greatest elongations of the pools are in a direction more or less parallel to and coincident with the axes of the anticlines.
3. With gas, oil, and water present together in the same stratum,

⁶U. S. Geol. Survey, Bulletin 398, Pl. V. B.

they are arranged in the order of their specific gravities, the gas at the top or absorbed in the oil, and the oil next below, but resting on the water which fills the remainder of the reservoir.

4. When water is absent, the oil is apt to occur near the bottom of the synclines but it may be part way up the anticlinal slopes, caught in superimposed synclines or in porous areas.

5. Oil and gas also occur in sealed reservoirs which may be located near the crests of anticlines, on the slopes, or in synclines. Water may or may not be present.

6. Oil and gas may occur on a "structural bench," i. e., where the dip of the strata changes from gentle to steep.

7. Oil and gas occur in other structures, which are not anticlines, but which serve in the same capacity, and the principles of the anticlinal theory (subject to its limitations) apply as in the case of normal anticlines.

8. Gas occurs mainly near the crests of anticlinal folds, but it occurs in greater volume beneath certain upward rises along the crests, called "domes."

9. Due to local changes in dip and porosity, gas occurs also in volume at many other points.

10. Oil in rocks saturated with water is found in the coarse grained porous areas but appears to be wholly excluded from many porous but fine grained areas in the same oil stratum, and this seems to be due in some way to capillary force and viscosity, the effects of which are not well understood.

ROCK PRESSURE IN GAS AND OIL WELLS.

The pressure developed within the casing of a gas or oil well, when the casing valve is closed, is called the "rock" or closed pressure. This pressure, which in general increases with the depth of oil or gas sand, varies from a few pounds up to 1500 or more, but the rock pressure in most of the great gas fields ranges from 300 to 800 pounds. Rock pressure, as observed, is always greatest when a field is first opened.

The open pressure of a well is the pressure exerted by the column of gas escaping with unobstructed flow from the casing. The greater the volume of gas discharged in a given time the greater the open pressure. This pressure which is rarely more than a few pounds is measured by some form of a gauge held in the current of escaping gas, but the open pressure of wells of less capacity than 1,000,000 cubic feet per day cannot be measured by the ordinary high pressure gauges. Resort must be made to the water or mercury column, or the anemometer.

The amount of closed pressure developed by a well is no indication

of its size and value. A small well may develop as great a closed pressure as a large one. A rough estimate of the size of a well, however, can be made by noting the time necessary for it to develop the maximum rock pressure after being closed. In a large well, the full pressure is attained almost instantly, in a few seconds, or in a minute at the longest. Wells of small volume on the contrary require several hours or even days to develop the maximum pressure obtaining in the pool. The time necessary for a well to develop its maximum rock pressure bears such a close relation to its size that generally the volume or value of a gas well is roughly estimated by comparing the amount of pressure developed per minute ("minute pressure") after being closed and the total rock pressure developed. Very accurate determinations are obtained by the use of the improved Pitot tube, which gives the capacity of a gas well in cubic feet.

The reason for the great difference in the volume of gas wells in the same pool lies in the fact that the porosity of the reservoir varies markedly from place to place. In the fine grained portions, the gas and oil escapes into the wells slowly, hence the flows are small. Large wells always indicate very open and porous reservoirs, from which the gas and oil can escape most freely. In general it may be stated that the greater the porosity and the rock pressure in an oil and gas reservoir, the greater is the size of the wells.

Cause of Rock Pressure. The cause of rock pressure in gas and oil wells has been the subject of much speculation and argument, and the controversy is still unsettled. Four theories have been advanced in explanation of rock pressure.

1. Hydrostatic pressure from water.
2. Pressure due to the expansive nature of the gas itself.
3. Pressure as the result of the weight of the overlying rocks.
4. Pressure from gaseous emanations from deep seated rocks.

In most fields, the oil and gas bodies are surrounded by salt water which, when penetrated by the drill, rises in the well to a certain height or even to the surface and above, in response to the pressure of the head of water contained in the rocks. This is the explanation of the artesian well, and E. Orton and I. C. White, and many other early investigators, once held that rock pressure in gas and oil wells similarly is due to direct water pressure acting under artesian conditions. Orton observed that in Ohio the pressure in most of the gas wells from the Trenton limestone was approximately the same as the calculated weight of a column of water of unit cross section reaching from the gas sand to the assumed level of the outcrop of this formation. In the case of oil wells, according to the artesian theory, whenever the elevation of the outcrop of the oil formation is sufficiently high above

the mouth of a well to overcome the loss of head through capillary friction, the pressure from the hydrostatic head will force the oil or water, as the case may be, up to or above the surface and the calculated weight of this column should represent the rock pressure. Rock pressure in general increases with depth in about the same proportion as the weight of a column of water extending from the surface to the same depth, but while this is strong evidence that water is generally an important factor in causing rock pressure, it does not follow that it is always a factor, and much less an important one.

The artesian theory assumes a porosity of the oil or gas stratum from well to outcrop, but this assumption in many instances is not warranted by the facts. Many oil sands vary greatly in porosity within short distances. In Oklahoma, California, and other western states some of the oil reservoirs are mere lenses devoid of water and sealed in by impervious strata. The so-called "Saginaw oil sand" (Chap. V) at the top of the Traverse at Saginaw appears to be a thin porous sandy or cherty limestone non-water bearing, of very limited extent, and sealed in by calcareous or bluish shale. Porous lenses appear to be characteristic of this formation, as it yields water only locally, at different levels and with small head in many cases. The deep Gordon and other sands beneath, in Pennsylvania and West Virginia, contain little or no water. Evidently under the conditions cited above water cannot be an important factor in causing rock pressure. Orton in his investigations of the New York gas fields found pressures of 1500 pounds, or much greater than could be accounted for under the artesian theory. In other fields also, rock pressures have been struck at depths much too shallow to be due to any hydrostatic head possible under the conditions. Thus the artesian theory breaks down as an explanation for all cases of oil and gas pressures.

It has been urged also that if artesian water is the cause of rock pressure, this pressure in a given field should remain practically constant instead of showing a more or less gradual decrease. This argument is not conclusive for, admitting that water is the primary factor in causing rock pressure in a gas pool, the pressure always tends to decrease inversely as the number and size of the wells opened. Owing to greater friction, the passage of water through the pores of a rock is much slower than that of gas, hence the invasion of the gas reservoir by water (or oil) may lag behind the escape of the gas, with a consequent fall in the rock pressure. This is especially pronounced in the case of close grained sands tapped by many wells. In open coarse grained rocks offering little resistance to the passage of water, the fall is much less rapid. To determine the maximum rock pressure in a

field where artesian conditions prevail, all of the wells must be closed for a period sufficient for the water to invade the gas reservoir and restore the full pressure of the hydrostatic head. The rock pressure in the oil and gas sands of some of the Pennsylvania fields has decreased to zero and in certain pools continuous pumping has tended to develop a vacuum⁷ in the sands.

The "expansion hypothesis" advocated by Prof. Lesley many years ago ascribes rock pressure to the expansive nature of the gas itself. Solid and liquid bituminous material in the reservoirs or in the associated rocks are supposed to give rise to gases which occupy many times more space than the liquid or solid sources. The gas tends to expand to fill this space and thus exerts pressure. This theory is apparently the true explanation for the rock pressure observed in sealed reservoirs and sands devoid of water and accounts satisfactorily for the variable pressures found in shale gas pockets.

In sands containing water under artesian conditions, the expansive force of the gas equals that exerted by water. Any increase in pressure by the former will tend to force back the water until equilibrium is again established through the increase in the capacity of the gas reservoir. In close grained sands, however, resistance to the passage of water is very great, hence the expansive pressure of the gas may become much greater than that from any possible hydrostatic head. This may explain the occurrence of exceptional pressures at depths too shallow to be accounted for under the artesian theory. I. C. White also suggests, as a possible explanation for the apparent agreement of rock pressures with the artesian pressure theory, that the long continued escape of small quantities of gas upward to the surface along fissures and joints has reduced the original pressure of expansion within the rock reservoir to that found on opening any new gas field, and in the case of small fissures and joints filled with water, the escape of gas would be arrested as soon as the resistance to the passage of the gas equals the pressure exerted by the head of water.

The third theory ascribes rock pressure to the weight of the overlying sediments. Against this theory, it is urged that oil and gas bearing rocks must be in a crushed state before the weight of the overlying rocks can be effective in reducing pore space and exerting pressure upon the contained liquids and gases. In the original argillaceous and calcareous muds and sands, now shales, limestones, and sandstones, gravity was a very effective force in causing consolidation and a reduction of pore space with a consequent increase of pressure on the liquid and gaseous contents. Rock pressure in the case of sealed reservoirs may be accounted for in part at least in this way,

⁷Bull. 454 U. S. Geol. Surv. 1911.

and it is possible that the pressures obtaining in some of the oil and gas reservoirs of southern Texas and Louisiana fields are due partially to the weight of the overlying and largely unconsolidated Tertiary sediments of the gulf coastal plain. In general, however, the attitude of the rocks and the geological conditions have so changed since the consolidation and cementation of the original sediments that, whatever pressures may have once obtained from the weight of overlying deposits, the existing rock pressures in hard indurated rocks are probably more directly due to other factors.

Under the fourth theory, the cause of rock pressure is referred to the pressure of gaseous emanations from deep seated or magmatic sources. In the zone of anamorphism, or of rock flowage, the pressures and temperatures are so great that gaseous and liquid solutions^s (chiefly the products of the processes of dehydration and decarbonation, but probably in part the result of emanations from magmatic sources) tend to be squeezed upward into the belt of cementation where lower pressures and temperatures obtain. The upper part of this belt contains the oil and gas reservoirs, and it is supposed that the gaseous and liquid solutions make their way upward and transmit their higher pressures and temperatures to the oil and gas bodies. While magmatic emanations are probably a factor in causing rock pressure, there is little evidence to indicate that they have been of more than very minor importance in causing the pressures observed in the great oil and gas fields of the continent, and certainly the emanation theory cannot account for the pressures obtaining in sealed reservoirs.

In conclusion it may be said that all four theories contain some elements of truth and that, while most of the existing evidence is inconclusive or contradictory, rock pressure is probably the combined result of the factors as given in the theories. In a given case, one or two factors are generally of much more importance than the others, and present evidence indicates that in most fields the cause of rock pressure can be ascribed chiefly to water acting under artesian conditions and to the expansive force of the gas itself.

SURFACE INDICATIONS.

Oil and gas "signs" in some fields are related to various surface indications. These may be divided into two classes: (1) those common to many fields, (2) those peculiar to certain fields.

In the first class are seepages of oil and gas. The seepages may be far distant from a pool (See fig. 8) and as a general rule the area of seepages is much larger than that of the productive territory. Large

^sC. R. Van Hise: Mon. XLVII, U. S. Geol. Surv., pp. 1017-1029.

and numerous seepages cannot be regarded as a more favorable sign than few and small ones. Some of the best fields gave little or no surface indications of their presence prior to their discovery. Large seepages may mean a very leaky reservoir and consequently little or no accumulation. Gas seepage is a poor indicator because marsh gas and other gases form so abundantly in many localities from decaying vegetation near the surface.

There are other surface signs peculiar to certain districts which have been taken as favorable indications. Two of these, characteristic of the gulf coastal plain in Texas and Louisiana, are the escape of hydrogen sulphide (H_2S) gas, and the "sour" waters. These phenomena are doubtless related to the formation of the salt bodies below, which in turn cause the formation of favorable structures for trapping the oil and gas in their migration upward.

In Wyoming, and many other western fields, anticlines are frequently discovered from surface observations or from a study of the field relation of the rock outcrops. On the Gulf Coastal Plain, low rises only a few feet in height sometimes indicate the presence of saline domes. More often, the anticlinal conditions are discovered only after considerable drilling.

In Michigan, gas springs, the occurrence of "shale" gas in the drift, a scum of oil on ponds and in wells, and bituminous smelling rock, are most abundant along the strike of the Devonian formations in the southeastern and northern portions of the Southern Peninsula. These signs have led to much fruitless drilling. The belt in which the oil formations outcrop must necessarily be one of leakage rather than accumulation.

The Survey has received many samples of highly bituminous "oil rock" from various parts of the State, especially from the regions mentioned above. Some of the black shales of the Coal Measures, the Sunbury (Berea), Antrim, and the Bell shales, and the Dundee and Trenton limestones give off a strong bituminous odor, especially when struck or heated. Such rocks are a source of oil and gas, but this does not mean that they necessarily contain valuable oil or gas pools, for reasons already given. In Michigan, the configuration of the surface deposits has no relation to the structures in the underlying rocks or to the oil horizons and the conclusions frequently drawn by drillers from the "lay of the land" are therefore of no value whatever. Extensive swamps with an abundance of gas (marsh gas, mainly methane) are also supposed by many to be highly indicative of accumulations of gas or oil in the immediate vicinity.

In many localities, a reddish oily scum with iridescent colors may be observed on the surface of the water, around springs, and in moist places. This nearly always proves to be iron oxide but it is often mistaken for oil.

CHAPTER III.

THE PORT HURON FIELD.

EARLY HISTORY AND DEVELOPMENT.

To Mr. C. H. Gordon¹ we owe a full report concerning oil and gas operations in the vicinity of Port Huron up to 1901. For many years it had been known that oil and gas existed in the underlying rocks in the vicinity of Port Huron, especially in the region to the east in western Ontario. In fact, the occurrence of these products in western Canada is mentioned in the reports of the Geological Survey of Canada nearly seventy-five years ago.

In 1860-61, the small and short lived Oil Springs field was struck, and later the Petrolia field was discovered. The latter, parallel to the Oil Springs pool, extends northwesterly for a distance of 12 miles nearly to the middle of Sarnia township, across the river from Port Huron. A third pool was found running parallel to the other two in Euphemia township. It was this pool which led to the sinking of several wells in Port Huron in 1886-7. Even before this, several wells had been drilled along the river for gas. In nearly all of these, gas was found in small or even considerable quantities in the top of the Dundee at a depth of about 500 feet. In 1886, C. A. Bailey drilled a number of wells. Well No. 1 (605 A. T.) was drilled 500 feet N, 1000 feet W, of the S E cor. of sec. 9, T 6 N, R 17 E, and two others appear to have been drilled in the same immediate vicinity. In these wells, the Dundee was struck at 543, 545 and 572 feet respectively. Gas was found in small quantities in the surface deposits just above the Antrim black shale, which is the bed rock in southeastern St. Clair county, and, also, considerable odorless gas was struck near the bottom of the "top lime" of the Traverse at depths varying from about 280 to 320 feet. The first show of oil, accompanied by some gas, occurred in the top of the Dundee at about 520 to 525 feet in all of the three wells.

A year later, F. L. Wells drilled a test well (585 A. T.) 1685 deep on the bank of Black river opposite Kern's brewery. There was a "blow" of odorless gas in the "top lime" of the Traverse, similar to those noted in the Bailey wells, and the usual show of oil and gas

¹Ann. Report for 1901, pp. 269-290.

in the top of the Dundee which was reached at 515 feet. A pocket of hydrogen sulphide gas under strong pressure was struck in the Upper Monroe beds, and the first conspicuous bed of salt in the Salina seems to have been struck at about 1555 feet.

No further interest was taken in the development of the field until 1898, when Mr. G. B. Stock, an operator from the Canadian fields, organized the Michigan Development Company and drilled a number of wells on what is known as the Goodrich property in the western part of the city very close to the old Bailey wells. According to statements of officials of the company, oil in relatively small yet commercially important quantities was struck in all of the wells in the sandy top of the Dundee limestone, which is struck at an average depth of about 520 feet in this part of Port Huron. At first, some of the wells yielded from 2 to 3 barrels per day, but gradually all of them decreased during the first few months until the average yield of each was about one-half barrel per day. With such shallow and cheap drilling the field was considered worthy of further development and new wells have been drilled from time to time until in 1910 there were twenty-one wells ranging in depth from about 500 to 650 feet, with a total production of about 10 barrels per day of 10 hours. The wells are on a tract of about 15 acres and are operated from a central pumping station (Pl. 1) by a 25 horse power gas engine which derives its motive power from gas obtained from the wells themselves. Mr. Stock also drilled a number of test wells north and west of Port Huron near Wadham's Station, at Abbottsford, and in Fort Gratiot township.

The showings of oil nearly everywhere in the district and the energetic example of Mr. Stock incited other men to undertake development work. Drillings were made on the old Sweitzer farm about three miles north of the Stock wells, at Valley Centre, and elsewhere.

A few years ago the Black River Oil Company drilled a number of wells along Black river north of the city. The company was succeeded in 1913 by the Michigan Central Oil Company which has made further exploration, and a number of their wells are reported to yield oil in quantities similar to the Stock wells, and also considerable gas.

While the quantity of oil is small the wells in the Port Huron district are long lived, most of the Stock wells having been pumped from 10 to 15 years without showing any great signs of exhaustion. It is the permanency of production which has caused the firm belief on the part of local prospectors that a large pool must exist somewhere in the vicinity of Port Huron. This permanency of flow seems to be characteristic of the Dundee in Ontario also, as the Petrolia field has been producing oil for over 45 years.

GEOLOGICAL CONDITIONS IN WESTERN ONTARIO.

From the study of the large number of drillings in western Ontario and at Port Huron, much light has been thrown upon the character, thickness and depth of the rock formations and the local geological structures. Early geologists supposed that the great Cincinnati and Nashville anticline, on the flanks and near the crests of which the great oil and gas fields of Ohio occur, extended northeastward from Ohio through the western end of Lake Erie into western Ontario. This now appears to be true only in part. According to E. Coste of the Canadian Survey, it runs from about Point Pelee on Lake Erie through Essex into Kent county and dies out in the northeastern part of the latter county. The Trenton along the supposed axis of the anticline which in Ohio is only 350 feet below sea level at Findlay and 800 feet near Lake Erie, is 1500 feet below sea level in Colchester township, Ontario, 1860 feet at Leamington and 2543 feet at Petrolia. Continuing northeastward from Petrolia the Trenton begins to rise, as it is 2310 feet below sea level near Inwood, 1166 feet at Stratford, 572 feet at Glen Allen, 310 near Alma, and 350 feet in Osprey township, Grey county.

According to the geological section² from Hamilton on Lake Ontario southwest to Courtright on St. Clair river, there is a steady dip only very slightly interrupted by minor folds and faults in Lambton county in the vicinity of the Petrolia, Moore and Euphemia pools. The line of section, however, is at an acute angle to the axis of the Cincinnati anticline and passes near the bottom of the sag noted above, hence the present drill holes might not show the presence of a gentle arch such as the Cincinnati anticline probably is, if it exists in Lambton county.

In Ohio, the Cincinnati anticline is very low in comparison with its great breadth. Superimposed upon it, however, are numerous minor anticlines and structural "benches" or terraces under which are found the many oil and gas pools of Ohio. Likewise in Canada there are local folds and undulations which run, not only parallel to the supposed course of the Cincinnati anticline, but also transverse to it. From a study of well records it appears that there are a number of these transverse folds in Ontario, having two principal courses—one practically east and west and the other northwest-southeast. From this, it follows that the structures in general extend toward the Michigan border, and perhaps across it into the state. Apparently this is the case at Port Huron, near Algonac, and at Wyandotte and Stony Island. The anticline at Port Huron seems to be directly in

²E. T. Corkill, 14th Rept. Ontario Bull. of Mines, 1905.

line with those in Enniskillen township, Lambton county, and evidently belongs to the same series.

The general dip of the formations is westward from Ontario into Michigan, therefore, according to the anticlinal theory, the oil and gas of the Dundee in the eastern part of Michigan would tend to migrate eastward into Ontario and perhaps much of the oil and gas found in the oil fields of Ontario, especially in the western part, has come from the rocks of eastern Michigan.

The Petrolia Field. There are three oil fields in Lambton county—the Petrolia, the Oil Springs and the Moore. The Petrolia was once the largest and most important field in Ontario. Its wells have been uniformly small but surprisingly long lived. Some of the wells have been pumped for nearly forty-five years, but the production has steadily fallen until the average yield per well is only 8 or 9 gallons per day. Through the use of gas engines, utilizing the gas which flows in considerable quantity from many of the oil wells, more than a hundred wells have been operated from a single pumping plant. After the pumps have been withdrawn many of the wells are bailed with fair success.

In the Petrolia field, the oil occurs in a porous horizon, "the lower lime," the Dundee (Corniferous), at about 400 feet, or about 65 feet below the top of the formation; but, in other fields, the oil horizon of the Dundee occurs from 45 to 170 feet from the top. In Michigan, the oil occurs near the top of the formation, salt water nearly always being struck when the formation has been penetrated to any considerable depth.

The logs of the wells given below show the general character of the formations in the Petrolia field.

TEST WELL, PETROLIA.

Loc.—Near Imperial Refinery. Record by H. P. H. Brummell, Geol. Survey Can. E. Rawlings, driller.

Elevation 667 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	104	104
Traverse:		
Limestone ("upper lime").....	40	144
Shale.....	130	274
Limestone ("middle lime").....	15	289
Shale.....	43	332
Dundee:		
Limestone ("lower lime").....	68	400
Limestone, soft.....	40	440
Limestone, gray.....	160	600
Monroe:		
Limestone, hard, white with hard streaks of sandstone from 2 to 5 feet in thickness.....	500	1100
Gypsum.....	80	1180
Salina:		
Salt and shale.....	105	1285
Gypsum.....	80	1365
Salt and shale.....	140	1505

The base of the "lower lime" is regarded as the base of the Traverse (Hamilton) by the Canadian geologists, but Michigan geologists draw the line at the base of the overlying shale, because this horizon is very sharply separated from the limestone below and therefore easily recognized in drilling. According to Lane's definition, the Dundee includes all the limestones below the shales down to the dolomites or gypsiferous shales of the Monroe formation. As this well does not reach the Trenton, the record of the Carman well drilled some years later is inserted to show the character, thickness and depth of the rocks down to the Trenton inclusive.

CARMAN WELL, PETROLIA.

Lot 11, Concession 11, Enniskillen, Lambton Co., Ontario, Drilled in 1900.

Elevation 667 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Blue clay	90	90
Traverse (Hamilton)	240	330
Streaks lime and shale. At St. Clair, 775 ft.:		
Dundee (Corniferous) limestone	190	520
Streaks of brown. At St. Clair about 900 ft.:		
Monroe Beds	690	1210
Brown, gray and black dolomite. At St. Clair, about 1630 ft.:		
Salina, gray and black dolomites:		
Salt	65	1275
Dolomite	20	1295
Salt and light streaks dolomite	170	1465
Salt	90	1555
Salt and dolomitic lime	50	1605
Salt	25	1630
Gray dolomite	10	1640
Salt	67	1707
Dolomite and salt	40	1747
Salt	138	1885
Dolomite and lime shale	130	2015
Salt	90	2105
Guelph and Niagara lime	275	2380
Rochester (Niagara) shale (red and dark)	60	2440
Clinton	90	2530
Red Medina	275	2805
Lorraine or Hudson River shale (light)	205	3010
Utica (dark)	165	3175
Trenton (Trenton, Birdseye and Chazy), 1015 ft. 6½ in. casing, no salt water or pressure of any kind found in Trenton, Finished December, 1900.	602	3777

Sarnia Township. As the productive oil territory extends north-west into the southeastern part of Sarnia township, and Sarnia lies directly in line of the longer diameter of the Petrolia field, there was more or less exploration in the vicinity of Sarnia.

In the Dicken's well, located in the southern part of the township, no Antrim black shale was found yet, just across the river in Port Huron, it is 82 feet thick in the F. L. Wells drill hole and 183 feet thick in the Junction well in the western part of the city. Evidently the 200 feet of surface in the Sarnia well represents an old pre-glacial channel as the surface materials in Port Huron are only half as thick. The top of the Dundee at Petrolia is 335 feet A. T. and 127 feet A. T.

at Sarnia, and this represents a drop of 208 feet to the westward in about 15 miles, or a dip of 14 feet per mile.

DICKEN'S WELL.

Loc.: Southern part of Sarnia near cor. Rose and Tecumseh streets. H. Mitchel, driller.
Record by H. P. H. Brummell.

Elevation 590± ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand and clay.....	130	130
Hard pan.....	55	185
Gravel.....	15	200
Traverse (Hamilton):		
Limestone.....	90	290
Shale.....	100	390
Limestone.....	5	395
Shale.....	68	463
Dundee (Corniferous):		
Limestone.....	77	540

In the King's Gristmill well, Sarnia, one and a half or two miles north of the Dicken's well, the drift is only 120 feet thick and there is 36 feet of the Antrim black shale. No oil was found, but there was a little gas at about 400 feet. The Dundee is 32 feet lower than in south Sarnia, showing a dip of nearly 20 feet per mile toward the north.

KING'S GRISTMILL WELL.

Loc.: One and one-half miles north of Dicken's well, Sarnia. Drilled in 1875 by E. Rawlings.
Record by H. P. H. Brummell, Geol. Sur. Can.

Elevation 589 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand.....	9	9
Blue clay.....	109	118
Hard pan.....	2	120
Antrim:		
Black shale.....	36	156
Traverse:		
Limestone.....	30	186
Shale.....	263	449
Limestone.....	5	454
Shale.....	40	494
Dundee:		
Limestone.....	60	554
Gray limestone.....	100	654
Monroe:		
Hard limestone.....	546	1200
Hard and flinty limestone.....	200	1400
Limestone with gypsum.....	105	1505

Courtright. Courtright is about 10 miles south of Sarnia on St. Clair river. In a well at this place, the top of the Dundee was struck at 46 feet A. T. or 81 feet lower than in south Sarnia, the average dip to the south being only about 8 feet per mile. The

fact that the Dundee is lower both to the north and south of Sarnia indicates that a fold crosses St. Clair river, probably through the southern part of Sarnia into the southern part of Port Huron. As will be seen later, this low fold appears to turn northwest in Port Huron and run along Black river valley.

COURTRIGHT WELL, ONTARIO.

Record by H. P. H. Brummell, Geol. Surv. Can., E. Rawlings, driller.

Elevation 588 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface sand and clay	132	132
Hard pan	28	160
Antrim:		
Shale, black	32	192
Traverse:		
Limestone	40	232
Shale and limestone	310	542
Dundee:		
Limestone, white	50	592
Limestone, gray	100	692
Monroe:		
Limestone, hard, white	370	1062
Sandstone (Dolomite, probably—B), (Sylvania—Lane)	32	1094
Limestone	400	1494
Limestone and gypsum	136	1630
Salt	22	1652
Gypsum	13	1665

EXPLORATIONS IN THE PORT HURON FIELD.

Port Huron. As previously noted, most of the wells in the Port Huron field are in the western part of the city. The G. B. Stock wells on the Goodrich property and the Bailey wells are close together. The former, 21 in number, are owned by the Michigan Development Co. of which E. J. Schoolcraft is president. The output is entirely consumed by the G. B. Stock Xylite Grease and Oil Co. in the manufacture of a superior grade of lubricants, for which the oil is said to be especially adapted. The oil is of a dark and heavy grade and a natural lubricant, being similar to the Petrolia or Lambton county oils which come from the same horizon.

The Bailey and the Stock wells are so close together that the log of only one from each group is given.

Michigan Geological and
Biological Survey.

Publication 14. Geological Series 11.
Plate I.



PUMPING PLANT OF THE MICHIGAN DEVELOPMENT COMPANY, PORT HURON.

THE STOCK WELLS.

Loc.: S. $\frac{1}{2}$, N. W. $\frac{1}{2}$, sec. 9, T. 6 N., R. 17.

Elevation 605 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Blue clay.....	100	100
Antrim:		
Black shale.....	87	187
Traverse (Hamilton):		
Limestone ("top lime").....	43	230
Soapstone, soft.....	70	300
Limestone ("middle lime").....	15	315
Slate or shale, dark.....	85	400
Soapstone.....	120	520
Dundee ("Lower lime"):		
Limestone, sandy, oil bearing.....	47	567
Limestone.....	33	600

The oil is found in the first 45 feet of the sandy top of the Dundee. The elevation of the top of the Dundee is 85 feet A. T., or 15 feet higher than in the F. L. Wells well to the eastward, and 23 feet higher than the Bailey No. 1, one-half mile southwest, and 93 feet higher than the Grand Trunk Junction well one and one-half miles southwest. This indicates the presence of a low anticline between the Junction and the Wells drill holes and in the vicinity of the Stock wells.

BAILEY WELL NO. 1.

Loc.: 500 ft. N., 1000 ft. W., sec. 9 T. 6. N., R. 17. About $\frac{1}{2}$ mile southwest of the Stock wells.

Elevation 605 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	100	100
Antrim shale:		
Black shale.....	100	200
Traverse (Hamilton) formation:		
Streak hard argillaceous limestone with FeS ₂	2	202
Soapstone (argillaceous marl).....	15	217
Limestone (top) blow of odorless gas at 280 ft.....	80	297
Soapstone (argillaceous marl).....	147	444
Limestone (middle).....	9	453
Soapstone with streaks of limestone at 518 and 525 ft.....	90	543
Dundee (Corniferous) limestone:		
Limestone (lower).....	125	668

GRAND TRUNK JUNCTION WELL.

Loc.: At Grand Trunk Junction near the N. E. corner, sec. 18, T. 6 N., R. 17 E.

Elevation 618 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	124	124
Antrim shale:		
Black shale, small amount of gas at 300 ft.....	183	307
Traverse (Hamilton) formation:		
Limestone (top).....	128	435
Soapstone.....	77	512
Limestone (middle).....	8	520
Soapstone.....	105	625
Dundee (Corniferous) limestone:		
Limestone (lower).....	147	772

At 680-685 feet there was "black water," at the bottom of the well, brine, and a show of oil at 710 feet.

The drop of the Dundee from the Stock wells southwest to the Junction well is 92 feet in about a mile.

WELL'S BORE HOLE.

Loc.: On bank of Black River near Seventh St. bridge, Port Huron. F. L. Wells, owner. Drilled in 1886-7. Record from samples.

Elevation 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface, mostly clay.....	102	102
Antrim:		
Black slate and shale.....	83	185
Traverse:		
Limestone (top).....	105	290
Soapstone with seams of limestones.....	225	515
Limestone (middle).....		
Soapstone.....		
Dundee:		
Limestone (lower) cherty at top with show of oil and gas.....	133	648
Monroe:		
Dolomitic limestone with indications of salt and gypsum.....	68	716
Marl and marly limestone.....	54	770
Hard dolomitic limestone.....	75	845
Bluish black marl with gypsum.....	58	903
Hard dolomitic limestone with show of brine and oil.....	42	945
Argillaceous marl with streaks of dolomitic limestone and gypsum.....	205	1150
Hard gray calcareous sandstone. (Oriskany?).....	95	1245
Bluish black argillaceous marl.....	10	1255
Dolomite and gypsum.....	300	1555
Alternating beds of salt limestone and shale.....	130	1685

This drilling is about a mile east and a little north of the Stock wells. The Dundee apparently occurs at 70 feet A. T. in the Wells bore hole, while to the west in the Stock wells it is 85 feet A. T. and 7 feet below tide in the Junction well. This indicates a westward rise of 15 feet to the Stock wells in about a mile, and then a rapid descent of 92 feet to the Grand Trunk Junction well in about a mile and a half. The first salt in the Salina seems to have been struck at

about 1555 feet, which at Petrolia (667 ft. A. T.) in the Carman well (see record on preceding pages) occurs at about 1210 feet. As the distance from the Carman well to the Well's bore hole is about 15 or 16 miles and the difference in elevation is 427 feet, the dip should be about 27 feet per mile to the northwest, or considerably greater than for the upper formations.

The Trenton was struck at 3175 feet or 2508 feet below sea level in the Carman well, and if we assume that the dip is the same for the Trenton as for the top of the Salina, the Trenton at Port Huron should be struck at about 2935 feet below sea level, or 3520 feet below the surface. As many of the deeper formations as the Clinton, Rochester, Medina, and Lorraine are known to vary markedly in the thickness in Ontario, the depth may be considerably more or less than this figure.

The Port Huron Salt Company drilled a deep well to the rock salt beds. The following record made from a complete set of samples is inserted with special reference to the character of the rocks encountered.

PORT HURON SALT CO. WELL.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Glacial drift	110	110
Antrim shale:		
Black bituminous shale; no effervescence	190	300
Traverse (Hamilton) Formation:		
Bluish gray dolomitic limestone; slight eff.	15	315
Mixed bluish and gray dolomitic limestone, probably thin bedded; eff. brisk in spots, owing perhaps to fossils.	50	365
Bluish calcareous shale somewhat plastic; eff. free	70	435
Even more shaly and plastic; dark rather than blue, yet not as dark as the Antrim.	135	570
Dundee (Corniferous) limestone:		
Light brown, limestone sharp, clear fragments; eff. very slow	30	600
Brownish, more granular; eff. fierce	50	650
Similar, with a little darker shaly matter, perhaps accidental	20	670
Same; with a sandy granular character, probably more porous	5	675
Same; eff. fierce	50	725
Almost similar, but a shade darker; no eff.	45	70
Similar; slight to slow eff.	25	795
Upper Monroe or Detroit River Series:		
Dolomite in light buff chips and white grains of anhydrite	20	815
Dark brown and granular; moderate eff.	40	55
Mainly similar to previous samples, but with a few white specks of gypsum as the same is damp, it may have been altered from anhydrite.	15	870
Maluy anhydrite	10	880
Dolomite; no eff.	5	885
Dolomite; moderate eff.	30	915
Dolomitic limestone evidently highly banded, fragments in pieces sometimes nearly 1 cm square x 1 mm thick at 915 ft.; light buff dolomitic limestone, same hue since 885; no eff.	30	945
Brown dolomitic limestone; moderate eff.; some grains of anhydrite?; no quartz.	40	985
Light buff dolomite, brisk eff. a moment only	15	1000
Mixed dark brown and brown bituminous dolomitic limestone; some of the grains eff. moderately, others not at all	5	1005
Dark dolomitic limestone; moderate eff.	25	1030
Similar	50	1080
Slightly lighter and with some anhydrite; slight eff.	35	1115
Dolomite with a little anhydrite	10	1125
Dolomite with anhydrite, and a gassy smell	25	1150
Dolomite; at first brisk and then slight eff.	10	1160
Sylvania?		
Cherty dolomite: blue gray, oxidized brown; a few grains eff. moderately; many grains of chert	5	1165
Largely a white cherty dolomite	20	1185
Lower Monroe or Bass Island Series:		
Apparently a light buff dolomite	25	1210
Darker dolomitic limestone; moderate eff.	5	1215
Light dolomitic limestone; moderate eff. with some anhydrite at 1235 ft.	20	1235
Light dolomitic limestone; moderate eff., rather more than at 1235	10	1245
Darker dolomitic limestone; moderate eff., strong gassy smell	20	1265
Dark, evidently thin bedded dolomite; slight eff.	20	1285
Lighter dolomite, moderate eff.	15	1300
Slate colored dolomitic limestone; moderately brisk eff.	5	1305
Bluish slate colored dolomitic limestone; moderately brisk eff.	20	1325
Dark bluish gray, and vari-colored dolomitic limestone; moderate eff.; gassy	20	1345
Dark dolomitic limestone, more granular, less slaty; moderate eff.	20	1365
Brownish dolomitic limestone; moderate eff.	5	1370
Color about like 1370; very moderate eff.	25	1395
Yellow; a very sharp change in color; slow eff.	13	1408
Dark slate colored dolomite; very slight eff., like 1395	8	1416
Dark slaty dolomite; very slightly eff., like 1395	24	1440
Equally dark, but with more of a brown tone, and white specks; with moderate eff. and greenish and reddish specks	20	1460
Dark slate colored anhydrite; very slight eff.	33	1493
Salina:		
Brownish salt	3	1496
Dark, slate colored, with impure salt and anhydrite	6	1502
Salt; while this appears impure and brownish, microscopic examination shows that the impurity is in separate particles, probably derived from the overlying bed.	4	1506
Blue and brown dolomitic anhydrite; slow eff. The color of the bands is like that of 1345 to 1395.	28	1534

PORT HURON SALT WELL CO.—Concluded.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Gray salt.....	10	1544
Like 1534; slight eff.....	35	1579
Brown salt at 1574 ft. Buff dolomitic anhydrite; slow eff.; color about like 1408, nearly white to light buff.....	4	1583
Bluish gray slaty anhydrite, one large piece; no eff.....	17	1600
Salt, white; anhydrite mixed in from above.....	15	1615
Brownish salt; mixed with anhydrite.....	14	1629
Clear white, coarsely crystalline salt.....	11	1640
White and brown salt.....	26	1666
Dark gray slate colored anhydrite; color same as at 1345 ft.....	29	1695
Clear white salt; specks of gray anhydrite probably from the overlying bed.....	5	1700
Brownish, impure salt.....	25	1725
Grayish salt with bands of anhydrite.....	10	1735
Dark gray salt and anhydrite.....	25	1760
Varicolored dolomite, green, reddish and buff grains, which effervesce slowly.....	20	1780
Varicolored dolomite; slow eff.; shaly and with anhydrite.....	25	1805
Buff dolomite; rather a dark buff in thin chips indicating original band- ing; some dark grains mixed in.....	20	1825
Slate colored salt and anhydrite.....	30	1855
Clear white salt.....	5	1860
Buff dolomite; slow eff.; with large pieces (1 cm) of a green slate with anhydrite.....	10	1870
Nearly clear salt.....	5	1875
Mixed green, reddish and colorless salt, anhydrite.....	10	1885
Gritty clay, plastic when wet, no eff.....	30	1915
Slate colored anhydrite, about color of 1345; no eff.; some clay.....	5	1920
Nearly clear white salt; partly gray.....	62	1982
Salt and anhydrite.....		2013
Gray salt with anhydrite.....		2022
Dark gray anhydrite, color of 1345.....		2027
Gray salt with anhydrite.....		2044
Gray salt with anhydrite.....		2048
Impure dolomite; slow eff. Varicolored.....		2260

There are many typographical errors in the depths as given for the samples from 2012 to 2044 ft.

Marysville. In the Marysville well, four miles south of Port Huron, the top of the Dundee is 73 feet lower than at Port Huron directly north, thus the average dip to the south is over 18 feet per mile. Salt water was struck at 745 feet and mineral water at 817, 970 and 985 feet. The division between the Dundee and the Monroe is not correct as the thickness given for the Dundee is much greater than any observed in Michigan.

MARYSVILLE WELL.

Loc.: Four miles south of Port Huron on the Binic farm. Drilled by Church & Company.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface, or Pleistocene:		
Clay.....	107	107
Gravel (dry).....	3	110
Antrim shale:		
Dark blue shale, streaks of black.....	188	298
Traverse (Hamilton) Formation:		
Gray limestone.....	97	398
Argillaceous marl thinly laminated and fissile.....	193	588
Dundee (Corniferous) limestone:		
Sandy limestone, porous, indications of gas.....	37	625
Limestone, gray (Upper Monroe in part).....	390	1015
Monroe Formation:		
Limestone, sandy (Sylvania?).....	80	1095
Limestone, dark gray, hard in places.....	55	1150

Wadham's Station. G. B. Stock drilled a well on the farm of Mr. Fair near Wadham's station, which is four or five miles northwest of Port Huron. The Dundee is 141 feet lower than at Port Huron, and this is equivalent to a dip of about 35 feet per mile. No oil or gas was reported.

THE FAIR WELL.

Loc.: Three-fourths mile southeast of Wadham's station, S. E. $\frac{1}{4}$, sec. 2, T. 6. N., R. 16 E.

Elevation about 655 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Gravel.....	4	4
Blue clay.....	110	114
Antrim:		
Black shale.....	122	236
Traverse (Hamilton) Formation:		
Limestone (top).....	230	466
Soapstone.....	105	571
Limestone (middle).....	45	616
Soapstone.....	95	711
Dundee (Corniferous) limestone:		
Limestone (lower).....	122	833

Abbotsford. A well was drilled by G. B. Stock on the F. A. Beard farm near Abbotsford, which is in Black river valley 10 miles northwest of Port Huron. The top of the Dundee was struck at the depth of 737 feet, or but about 25 feet lower than at the Fair well five or six miles to the southeast. This indicates that the steep northwest dip from Port Huron to Wadham's station becomes almost flat from the latter place to Abbotsford. Only a slight flow of oil was struck and this was 76 feet below the top of the Dundee.

BEARD'S WELL.

Loc.: Abbotsford, near S. E. corner sec. 8, T. 7 N., R. 16 E. F. A. Beard farm. Drilled by G. B. Stock.

Elevation about 655 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Marly clay.....	30	30
Tough blue clay.....	86	116
Wash gravel.....	22	138
Antrim:		
Black shale (heavy flow of mineral water at 140 ft.).....	100	238
Traverse (Hamilton) Formation:		
Limestone (top).....	217	455
Soapstone.....	122	577
Limestone (middle).....	4	581
Soapstone (brine at 587 ft.).....	156	737
Dundee (Corniferous) limestone:		
Limestone (lower); slight flow of oil at 813 ft.....	96	833

Valley Center. Valley Center is 20 miles northwest from Beard's well and 30 miles from Port Huron. Since the top of the Dundee was not reached at Valley Center, the top of the Traverse must be taken as a basis of comparison. In Beard's well, this is struck at 417 feet A. T. and in the Valley Center at 841 feet, or 423 feet lower. This gives an average dip of about 14 feet per mile to the northwest. The Traverse formation, however, thickens rapidly to the west, increasing from 313 feet in the Stock wells to practically 500 feet at Beard's. This indicates that the Dundee must dip much more than the figure given above. If we assume that the Traverse is 500 feet thick at Valley Center, (probably it is more, as at Saginaw and Bay City it is 600 to 650 feet thick), the top of the Dundee at Valley Center should be struck at a depth of about 1341 feet, (536 feet below sea level) or respectively 454 and 621 feet lower than at Beard's and at Port Huron. This would give an average dip for the Dundee from Port Huron to Valley Center of nearly 21 feet per mile, and nearly 23 feet from Beard's to the latter place.

OIL AND GAS IN MICHIGAN.

VALLEY CENTER WELL.

Loc.: S. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$, sec. 27, T. 9 N., R. 13 E.

Elevation 805 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Red sand and loam.....	5	5
Quicksand.....	90	95
Clay.....	22	117
Sand and gravel with plenty of pure water.....	32	149
Coldwater shale:		
Sandstone.....	5	154
"Conglomerate".....	20	174
Sandstone.....	30	204
(This sandstone and conglomerate may be the Richmondville or another stray sandstone horizon at some distance above the base of the Cold- water.)		
Slate (blue shale).....	10	214
Soapstone.....	175	389
Slate (shale).....	150	539
Berea sandstone:		
Limestone.....	10	549
Sandstone.....	20	569
Antrim shale:		
Shale changing to soapstone below.....	272	841
Traverse (Hamilton) Formation:		
Limestone.....	35	876

Imlay City. Two deep holes respectively 802 and 1020 feet deep were drilled by Walker & Co. at Imlay City, Lapeer county, and the record of the deeper one is given below.

IMLAY CITY WELL.

Walker & Co., owners. Record from driller's notes and from samples.

Elevation 830 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Red sand	11	11
Quicksand (mostly)	60	71
Hardpan	4	75
Gravel	16	91
Lower Marshall? and Coldwater:		
Blue argillaceous shale; quite soft and somewhat calcareous	19	110
Blue shale. (no samples)	80	190
Flow of fresh water at 190 ft.		
Red shale (no sample)	8	198
Light gray argillaceous shale, very sandy. Under microscope about equal parts of somewhat rounded grains of sand and of clay; sand 1-500 in. in diameter	202	400
Light bluish gray argillaceous shale, almost gritless	30	430
Very sandy argillaceous shale, light gray, almost gritless. A few partly rounded grains of sand 1-1000 in in diameter	90	520
Argillaceous shale, light bluish gray, almost gritless. A few partly rounded grains of sand 1-1000 in. in diameter	75	595
Limestone.	7	602
Argillaceous shale, light gray; few very minute shale grains at 602 ft.		
Argillaceous shale, light gray	28	630
Argillaceous shale, bluish gray, gritless	20	650
Argillaceous shale, bluish gray	20	670
Argillaceous shale, grayish drab	40	710
Weak brine at 708 ft.		
Argillaceous shale, dark gray	30	740
Argillaceous shale, very dark drab, gritless	15	755
Argillaceous shale, gray	15	770
Argillaceous shale, dark blue	12	782
Argillaceous shale, dark blue, gritless	8	790
Sandstone.	10	800
Argillaceous shale, light blue, somewhat sandy	5	805
Argillaceous shale, light blue, gritless	9	814
Argillaceous shale, light blue	51	865
Argillaceous shale, dark bluish drab, somewhat slaty, hard	10	875
Argillaceous shale, light bluish, soft	25	900
Argillaceous shale, light bluish, gritless, soft	15	915
Argillaceous shale, dark blue, gritless soft	10	925
Argillaceous shale, light blue, gritless soft	35	960
Argillaceous shale, gritless, soft	15	975
Argillaceous shale, gritless, soft, light blue	10	985
Argillaceous shale, light blue, gritless, soft	25	1010
Argillaceous shale, dark bluish drab, slaty and rather hard and gritless	5	1015
Reddish shale	5	1020

Fort Gratiot Township. Two wells were drilled on the Sweitzer property, one and a half miles north of the Stock wells. The Dundee is about 33 feet deeper than in the latter wells and this indicates a dip of about 20 feet per mile to the north. A show of oil was reported at 558 feet in the No. 1 well and a small quantity was obtained after shooting it at 568 feet.

SWEITZER WELL.

Loc.: Fort Gratiot Twp., S. W. $\frac{1}{4}$, sec. 33, T. 7 N., R. 17 E.

Elevation about 610 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Soil and sand.....	5	5
Clay.....	100	105
Hard pan and marl.....	15	120
Antrim shale:		
Black shale.....	100	220
Traverse Formation:		
Limestone, white with thin strata of soapstone.....	60	280
Soapstone.....	278	558
Dundee (Corniferous) limestone:		
Limestone (lower).....	62	620

G. B. Stock drilled a well on the farm of Mr. Shaw about six miles north of the Stock wells in Port Huron. In this well, the top of the Dundee occurs at 60 feet above sea level, or practically at the same height as in the Stock wells. To the north of the Shaw well, the formations are known to descend rapidly, as in the Pabst well 3 miles south of Lexington there are more than 252 feet of Antrim shale, including a thin bed of limestone at the top. A showing of oil was said to have been struck at 557 feet in the Shaw well, but this was not tested and the well was abandoned.

The record of the Pabst well above mentioned is faulty or incomplete, hence of little use in correlating horizons or tracing structures.

SHAW WELL.

Loc.: Fort Gratiot Twp., S. E. $\frac{1}{4}$, sec. 8, T. 7 N., R. 17 E.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand and gravel.....	5	5
Purple clay or mud.....	30	35
Gravel.....	3	38
Blue clay.....	79	117
Antrim shale:		
Black shale.....	45	162
Traverse (Hamilton) Formation:		
Limestone.....	203	365
Soapstone.....	95	460
Limestone (middle).....	15	475
Soapstone.....	65	540
Dundee limestone:		
Limestone (lower).....	115	655

THE PORT HURON ANTICLINE.

From the data afforded by the numerous borings in the vicinity of Port Huron, a low fold (Fig. 2) crosses St. Clair river from Sarnia, passes northwestward through the southern and western parts of

Port Huron, and, veering to the north, extends along Black river. The anticline pitches very gently along its course, and, on the west, it is bordered by a syncline pitching in the same direction. Since the anticline pitches in a general northwesterly direction, the oil and gas would tend to migrate to the southeast along the crest unless arrested by some cross fold, of which there is no present indication.

THE OIL HORIZONS.

Until a comparatively few years ago, it was supposed that the Dundee was the only oil bearing horizon in Ontario. Prospecting in the deeper formations disclosed the fact that the Guelph or Niagara are locally very "vesicular" or fissured and contain oil in great quantities. The porous nature of the reservoirs permitted a ready flow of oil and some of the wells yielded more than 1200 barrels per day. This formation also yielded great quantities of gas in Kent and also in Essex county. The Medina with three "pays" was also found to be a great gas producer in the Niagara peninsula. The Onondaga in Kent county, however, has four gas horizons. The wells are very large, one producing 7,000,000 cubic feet per day and 17 averaging two and one-half million cubic feet. The Trenton formation, however, has been a source of disappointment wherever struck in Ontario.

Conclusions. From the foregoing facts, it is reasonable to conclude that, since the Dundee, Niagara, Medina, and Onondaga are oil bearing in western Ontario, the same formations may be productive a few miles to the west in Michigan, especially in the vicinity of favorable structures such as occur at Stony Island, Wyandotte, and Port Huron.

HURON AND SANILAC COUNTIES.

The early salt wells. In the early days of lumbering and salt manufacture, many wells were drilled along the Lake Huron shore from Saginaw bay to Sanilac county. These wells obtained their brines from the Berea grit, or from the Richmondville sandstone. The F. Crawford wells at Caseville were from 1760 to 2270 feet in depth, the Pigeon River Furnace Company (later Lake Huron Iron Co.), 1760 feet, the Port Crescent wells about 1250 feet, Port Austin 1225 feet, Grindstone City 1080 feet, New River 1029 feet, Port Hope Salt Co. 787 feet, Harbor Beach 715 to 1900 feet, and the White Rock wells 700 to 1311 feet.

The brine bearing horizon dips to the westward increasing in depth from 700 to 800 feet at White Rock in the eastern part of Huron county to about 2000 feet in the western part. The Berea in Huron county

is a coarse grayish white sandstone full of pure strong brine, but in none of the drill holes was the occurrence of either oil or gas noted.

The Geological Sections. As there are no reliable logs of any of these numerous early salt wells, the following generalized sections showing the probable character and thickness of the formations in Huron and Sanilac counties are inserted.

GEOLOGICAL COLUMN IN HURON COUNTY.

	Thick- ness, feet.
Surface:	
Lake sands, clays and till.	0-50
Saginaw Coal Measures (Present only in extreme southwestern part of county):	
Black, white and blue shales, coal and sandstone.	75
Marville limestone (Present along western shore):	
Sandy yellow limestone, crossbedded sandstone and a little dolomite.	50
Michigan Series (Present in western quarter only):	
Light gray shale with gypsum and pyrite; salty bluish shales; argillaceous hydraulic limestones.	230
Napoleon or Upper Marshall (Absent from most of eastern half):	
Clean white sandstone, sometimes with an olive tint or brown from specks of pyrite.	300
Lower Marshall (Absent along eastern margin of county):	
Flags and sandstones, green weathering red, with beds of blue micaceous shale, white sandstone, nodules of iron carbonate, and thin seams of "peanut" conglomerate.	260
Coldwater shales:	
Blue shales with sandy streaks, often ripple-marked, frequently charged with carbonate of iron.	896
Sunbury (Berea) shale:	
Black shales.	75
Antrim shale:	
Black shales.	456
Traverse (Hamilton) Formation:	
Limestones and shales with black Bell (Marcellus) shales at the base.	615
Dundee (Corniferous) limestone:	
Limestones locally bituminous; water bearing near the base.	120
Monroe (including the Salina):	
Dolomites, anhydrite, shales and salt beds; dolomites heavily water bearing at several horizons.	1200 +
Niagara (Guelph and Lockport):	
Dolomites with some limestone and shale and occasional sandstone lenses; water bearing especially at some distance below the top; yields oil in Ontario.	400
Rochester, Clinton, Medina, and Lorraine shales:	
Mainly shales, red green, and black and locally sandy down to the heavy blue shales of the Lorraine.	700
Utica shale:	
Black and bituminous shales.	50
Trenton limestone:	
Dolomites and limestone with oil horizons near the top and water farther down.	300 +

The thicknesses given in the above section are estimated mainly from the records of wells in Huron and Sanilac counties. Since the formations dip to the west, the depth to a given horizon grows progressively greater in that direction.

GENERALIZED SECTION FOR SANILAC COUNTY.

	Thick- ness, feet.
Pleistocene or glacial drift:	
Sand, clay and till.....	0-200
Lower Marshall (absent in eastern and southern part of county):	
Sandstone and "grindstones".....	60-100
Coldwater shales:	
Blue shales.....	100-200
Sandstone (Richmondville).....	50-80
Blue shales.....	200-250
Black shales (Sunbury).....	50-150
Berea sandstone.....	30-50
Antrim shale:	
Darker below.....	100-150
Traverse (Hamilton) Formation:	
Blue calcareous shales and limestones frequently dolomitic.....	100-150
Dundee limestone.....	125 +
Monroe Formation including Salina:	
Dolomite, calcareous and argillaceous marls, anhydrite and rock salt.....	800 +

CHAPTER IV.

THE SOUTHEASTERN DISTRICT.

INTRODUCTORY STATEMENT.

The southeastern district includes that of Port Huron, but for several reasons it has seemed best to discuss the latter as a separate oil field. The southeastern district, lying close to the Toledo oil fields and to two great industrial centers, and including areas in which there are abundant signs of oil and gas, has received a disproportionate amount of attention in the past from oil and gas prospectors. A large number of holes have been drilled from Port Huron to the Ohio line. Many of these were drilled for salt or water and others for oil and gas, but in none of them has there been any but the most meager discoveries of either of the latter products.

ROCK STRUCTURES.

These explorations indicate that all of the formations from the Ohio line to Macomb county dip in general from 20 to 30 feet per mile to the northwest toward the central part of the basin. The only marked disturbances which break the monotony of this northwestward slope appear to be at Stony Island, Wyandotte, and Algonac.

While this general northwest dip of the rocks constitutes a great monocline, a large part of it is included in what is really a very low anticlinal fold extending at least down to the Traverse formation,¹ and pitching gently northwest. The limbs of the fold extend from Adrian to Pontiac, a distance of nearly 70 miles, the axis passing through Ann Arbor. The steepest dip at right angles to the axis appear to be not more than 5 to 7 feet per mile. The actual drop of the Antrim from Ann Arbor to Pontiac is 231 feet in 34 miles, and to Adrian on the other side 195 feet in about the same distance.

Such a structure might reasonably be expected to contain pools of oil and gas, but deep drill holes at Ypsilanti and Ann Arbor encountered no appreciable quantities of either. In explanation of why this structure does not apparently contain these products, Dr. W. H. Sherzer advances the theory, that, since the anticline pitches to the northwest, the oil or gas works its way upward and southeast-

¹W. H. Sherzer, Geological Report of Wayne County, Pub. 12, Geol. Ser. 9, 1911.

ward along the crest of the anticline to the outcrops of the oil formations in Wayne and Monroe counties, and thus escapes. In this connection, it may be noted that the anticline is so broad, flat, and ill defined that it could have only slight effect on the concentration of oil and gas in bodies of commercial importance.

RELATION OF SURFACE SIGNS TO OIL AND GAS HORIZONS.

Signs of oil and gas abound in the area underlain by the Berea grit and Devonian formations which occur in a belt extending from St. Clair county to the Ohio line. In some places oil accumulates as a scum on ponds, around springs, and in wells, giving a very offensive odor to the water and rendering it unfit for domestic or stock use. Some springs give off gas in amounts sufficient for ignition. Gas is struck in surface wells throughout the belt underlain by the Devonian formations, and nearly a hundred wells in St. Clair, Macomb, Oakland, and Wayne counties yield gas enough for household purposes, many of the wells being utilized by farmers in this way. The pressures vary from a fraction of a pound to nearly 100 pounds, but range ordinarily between 5 and 40 pounds. The life of such wells is generally from 6 to 8 years, but some of them have yielded gas for more than 15 years. Others exhaust themselves in a few weeks or months. The shale gas wells are worth utilizing to a much greater extent than they are at present. One well in Muskegon county, reported to yield 2500 feet per day, is allowed to run to waste. This well would furnish fuel and light for several ordinary families.

Similar surface signs are in the northern part of the State where the Devonian formations underlie the drift. The Killmaster and Atlanta gas springs are in the vicinity of the Berea horizon, and the gas well at Onkama (Chap. VIII), Manistee county, struck in January, 1912, is in heavy drift directly over the Antrim black shales.

The Dundee limestone is locally very bituminous and has a strong oily odor. A semi-fluid bituminous or oily matter is sometimes found in cavities of fossils and in crevices and the whole rock is generally more or less impregnated with oil. The Antrim shale is very black and sometimes contains 25 per cent of bituminous matter, smells strongly of petroleum, and nearly always yields small quantities of gas. In places it is so bituminous that it can be burned.

The Traverse formation in the central and northern parts of the state is 600 to 650 feet thick, and is known to produce oil at three different horizons (See Chap. V) at Saginaw. In southeastern Michigan, it is much thinner, being only about 300 feet thick at Port Huron and less than 200 feet thick in the southeastern corner of the State. The bituminous basal (Bell, or Marcellus) shales are not characteris-

tic of the Traverse in the southeastern district, and perhaps this explains why it does not yield more abundant signs of oil and gas in this region.

The Berea sandstone, a coarse gray sandstone full of brine even near its outcrop, is from 100 to 200 feet thick and lies at the base of the Coldwater shales. Its course through Oakland county is apparently marked by a line of brackish or salt wells. It cannot always be recognized in well records that do not go to deeper and more characteristic and recognizable horizons, for, in some localities, stray sandstones very similar in appearance occur in the Coldwater above the Berea horizon. The Berea is generally overlain by a black shale at the base of the Coldwater, known as the Berea or Sunbury shale. Thus the Berea is overlain and underlain by black bituminous formations, giving ample sources for the gas it nearly always contains in considerable quantities and yields to the overlying drift.

THE FOLLOWING TABLE GIVES A NUMBER OF THE SHALE GAS WELLS OF MICHIGAN, THE OWNERS, LOCATIONS AND PRES-SURES OF THE WELLS AND THE ROCK FORMATIONS IMMEDIATELY BENEATH THE DRIFT.

Owner.	County.	Township and range.	Depth.	Pressure lbs. per sq. in.	Rock formations below.
C. L. Rowe, Buelah.....	Benzie.....	N. E. 1 of Sec. 28, T. 28 N., R. 15 W.....	205	?	Antrim.
Franz Elwart, Warren.....	Macomb.....	.....	69	?	Antrim.
Wm. H. Hanekow, Warren.....	Macomb.....	.....	72	?	Antrim.
Wm. L. Hartsig, Warren.....	Macomb.....	.....	90	72	Antrim.
Otto Jacob, Warren.....	Macomb.....	Sec. 20, Warren Twp.....	60	?	Antrim.
August Mielke, Warren.....	Macomb.....	.....	98	45	Antrim.
A. R. Peters, Warren.....	Macomb.....	.....	93	?	Antrim.
Alex. Smith, Warren.....	Macomb.....	.....	71	?	Antrim.
Henry Vohs, Warren.....	Macomb.....	.....	50	?	Antrim.
Max Wolgast, Warren.....	Macomb.....	Sec. 18, Warren Twp.....	68	25	Antrim.
Jno. Dobberowsky, Grosse Point Farm, Warren.....	Macomb.....	.....	?	25	Antrim.
H. W. Leonard, Onekama.....	Manistee.....	Sec. 22, Onekama Twp.....	437	185	Antrim.
Robt. Jackson, Ravena.....	Muskegon.....	.....	?	?	Coldwater.
Louis Granow, Royal Oak.....	Oakland.....	.....	108	39	Antrim.
Frank Grosjean, Southfield.....	Oakland.....	.....	105	?	Berea or Sunbury.
Wm. Hlzlzinger, Royal Oak.....	Oakland.....	Sec. 22, Royal Oak Twp.....	115	39	Antrim.
Edw. Landau, Royal Oak.....	Oakland.....	.....	95	?	Antrim.
Henry Langer, Royal Oak.....	Oakland.....	.....	102	43	Antrim.
E. McHugh, Redford.....	Oakland.....	Southfield Twp.....	20	?	Berea or Sunbury.
Wm. J. Purdy, Redford.....	Oakland.....	Sec. 24, Southfield Twp.....	105	Weak now.	Berea or Sunbury.
E. A. Starr, Royal Oak.....	Oakland.....	N. E. 1 of Sec. 8, T. 1 N., R. 8 E.	?	?	Berea.
N. E. Springsteen, Royal Oak.....	Oakland.....	Sec. 9, T. 1 N., R. 11 E.	116	Gas with water.	Antrim or Berea.
Frank Farmerier, Royal Oak.....	Oakland.....	Royal Oak Twp.....	108	16	Antrim.
M. J. & L. J. Harrow, Algonac.....	St. Clair.....	.....	300	10	Antrim.
H. E. Harman, Willis.....	Washtenaw.....	Sec. 26, Augusta.....	65	?	Antrim.
Irving Becker, Detroit.....	Wayne.....	Redford Twp.....	65	?	Antrim.
Jno. Desgrandchamp, North Detroit.....	Wayne.....	.....	122	Exhausted now.	Antrim or Traverse.

MONROE COUNTY.

Monroe county² lies close to the oil fields of northwestern Ohio. There is an area in the western part where surface signs of oil and gas are especially abundant. Naturally it received early attention from oil and gas prospectors. About 15 deep wells have been drilled in the county, of which seven penetrate the Trenton.

The Cincinnati anticline extends in a general northeasterly course from the vicinity of Findlay, Ohio, across Lake Erie into Essex and Kent counties of Ontario, where it apparently dies out. On either side of the axis the formations slope away at comparatively flat dips. The general dip northwestward from the crest into Monroe county is only about 30 feet per mile and there are apparently no local disturbances in the general slope. Monroe county is situated well down on the northwest slope of this great anticline, and, therefore, the oil and gas may have been drained to the southeast towards the fields of northern Ohio. Apparently the only hope of finding oil in this part of the State lies in the presence of local anticlines or terraces of which we now have no knowledge, or in porous areas or lenses sealed in by impervious rocks.

The southeastern part of the county is the most promising portion as it is nearest the crest of the Cincinnati anticline and the northern Ohio fields. Of the 15 or more wells drilled for oil, the one farthest southeast, the Potter well, was the most productive, and the ones farthest away from the axis were "dry" holes. The Potter well, is located in N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, sec. 22, Erie township. It was begun in November and completed December 10, 1899, reaching a depth of 1667 feet, and striking the Trenton at 1555 feet. A little oil and gas were struck. The well has been bailed out several times, once yielding about 10 barrels of oil. The gas, with an original pressure of 25 pounds, was piped to the house and used for cooking and lighting purposes. Most of the other wells made showings of oil and gas, but none as large as the Potter well.

Monroe. At Monroe several wells were drilled, three of them to the Trenton. None yielded more than a trace of oil and a little gas. The record of the Moore well, as revised from Vol. VII, Part I, is given below:

² Sherzer: Monroe County, Vol. VII, Part I, p. 190.

MOORE WELL.

Loc.: Monroe, Monroe County. Record from samples.

Elevation 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	40	40
Lower Monroe:		
Bluish shale, with only a small amount of eff. calcareous matter.....	5	45
Bluish shaly dolomite, with quite a little slowly eff. matter, and a large residue in lower part.....	35	80
Yellowish limestone, briskly effervescing.....	230	310
Here and at 35,500 and 650 ft., samples of a white earthy powder of cal- cite and dolomite, with a trace of gypsum (probably a chemical pre- cipitate from underground water.)		
Water, 3000 gallons per hour between 280 and 297 ft.		
Dolomite at 340 ft.; effervesces slowly when in fine powder; contains much anhydrite of a dark buff color.....	170	480
Buff dolomite at 450 ft. like the sample above, eff. moderately fast, with an occasional fragment of the green shale, little or no sulphate of lime.		
Light colored dolomite.....	200	680
Eff. moderately at 500 ft. with much anhydrite.		
Eff. slowly at 500 and 650 ft.; an occasional grain of sand; no anhy- drite.		
Light gray dolomite; eff. slowly; reacts for gypsum.....	20	700
Niagara—Guelph and Lockport:		
Light yellowish to bluish gray dolomite; eff. slowly; quite ferruginous, no gypsum.....	130	830
White arenaceous dolomite; eff. slowly; with grains of quartz, sand and a very little magnetite.....	70	900
Gray dolomite, eff. slowly with a trace of quartz. Last limestone before shale.....	160	1060
Rochester, Medina?		
Greenish and reddish shales, eff. slightly; mostly clay.....	90	1150
Lorraine or Maysville:		
Bluish gray, somewhat ferruginous shales, slight eff.....	420	1570
With minute granules of quartz at 1400 ft.		
Green and red ferruginous shales, slightly eff. with a trace of magnetite. (Particles of the drill?).....	85	1655
Utica:		
Next above Trenton, black bituminous shale, eff. slightly, fusing with an aromatic odor and intumescence to a blebby enamel; a little finely divided quartz.....	80	1735
Trenton:		
First screw, buff colored dolomite; hard, with slow eff. At 1742 gas, odorless, with white flame; considerable salt water?		
Third, fourth, fifth and sixth screws in Trenton, buff colored limestones..	15	1750

LASALLE* WELL.

Loc.: Gadjry Saul Farm, LaSalle, Monroe county. Owners, Bengood Oil Co., Fostoria Michigan. Drilled in 1914 by Schrier & Kerr, Lancaster, O. Record furnished by Geo. T. Bench, Fostoria, Michigan. Reported by H. L. Osborne.

Elevation between 590 and 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Drift.....	40	40
Drive pipe 40 ft.		
Lower Monroe or Bass Island Series:		
Hard gray lime (dolomite).....		
Small stream of water at 50 ft., large at 100 ft.....	260	300
White lime (dolomite).....	60	360
Gray lime (dolomite).....	30	390
Niagara (Guelph and Lockport):		
White lime.....	490	880
Rochester shale and Clinton?		
Blue shale and shells.....	165	1045
8 inch casing to 885 ft.		
Richmond and Medina:		
Red rock.....	45	1090
Gray shell.....	10	1100
Pink rock.....	50	1150
Lorraine or Maysville shales:		
Gray shell.....	325	1475
Utica shale:		
Brown shale.....	160	1635
Trenton rock (Trenton, Birdseye and Chazy?).....	850	2485
Little salt water at 2485 ft.		
St. Peters? sandstone:		
White sandstone.....	31	2516
"Big salt" water at 2510 ft.		

* Record received as this report went to press.

Strasburg. About 1907, a well was put down by the Strasburg Oil Company on the Hansberger farm near Strasburg. It reached the Trenton at 1884 feet, and was shot with 200 quarts of nitroglycerin. From 1950 to 1989 feet there was a very small showing of oil and gas. A small flow of water was struck between 600 and 625 feet, and a larger flow just above 690 feet. A good driller's record and set of samples were obtained from which the following record was compiled by A. C. Lane:

STRASBURG OIL & GAS CO. WELL NO. 1.

Loc.: Hansberger farm, Monroe county. J. P. Harnden, Driller, 1907.

Elevation 625 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene drift:		
Soil, sandy loam, light clay and gravel	18	18
Lower Monroe (below Syl[van]ia) Bass Island Series:		
Raisin river and Put-in-Bay dolomites	357	375
300-375, hard with moderate eff.		
Water at 25 ft.		
Water at 45 ft. 10 gallons a minute.		
Flow at 68 ft. 160 gallons a minute.		
Flow at 345 ft. 240 gallons a minute.		
Tymochtee shale horizon:		
Dolomite and gypsum or anhydrite	20	395
375-385, hard, moderate eff. A little anhydrite.		
385-395 with anhydrite and much gypsum. Slow eff.		
Greenfield dolomite. Dolomitic limestone	90	485
395-415, a little.		
455-485, the upper samples not so hard; the rest pure, light colored, hard, massive, dolomitic limestone with moderate eff., except the last which contains blue shale and grit as well as dolomite.		
Cased well to 485 feet—no water.		
Anhydrite, hard blue shale and dolomite, a little anhydrite, which may have come from layer below	55	540
485-510 "Hard" blue shale, almost no eff.		
510-540, "Hard," moderate eff.		
Salina Horizon?		
Anhydrite	20	565
540-565, slow eff., under the microscope mainly anhydrite, light brownish.		
Dolomite mainly, all "hard"	35	600
565-585, slow eff. A little anhydrite which may have dropped in from above.		
Anhydrite	25	625
600-625, moderate eff., "a little water at this depth;" under the microscope, gypsum as well as anhydrite, the former probably produced from the latter by water, as the bed is reported "hard."		
Dolomite (with water)	65	690
625-655, is a brown sandy looking kind of dolomite that often occurs near water course, but there is really only about 1 per cent sand. Compare Morton well, Wyandotte, 230-240, 410, 460, 720 and 780 ft. 655-690, is also dark and "very hard," more water, filled within 200 ft. of the top, pulled casing, sample of water taken.		
Somewhere from here down should be put the base of the Monroe and Salina and the top of the Niagara or Guelph, the brown sandy looking oily dolomites which occur in this well between 625 ft. and 900 ft. being represented at—		
Wyandotte, between 1235 ft. and 1510 ft.		
Dundee, between 618 ft. and 1193 ft.		
Nogard well, between 569 ft. and 1420 ft.		
Britton, between 1200 and 1550 ft.		
Milan, between 1400 ft to 1540 ft.		
With rock salt at the bottom.		
Monroe, from 500 down.		
Cheboygan, from 1460 down.		
Niagara (Guelph and Lockport):		
Brown dolomite	110	800
690-695, brownish, sandy, "dry, no water," crystalline enough for Guelph.		
695-800, dolomitic limestones with moderate (at 775 ft.) eff. and bluish light colors.		
Light dolomitic limestone	20	820
800-820, is light colored with brisk eff. and under the microscope a clear limestone.		
Brown dolomite	80	900
820-900 are "very hard," brown, sandy looking, almost exclusively carbonate with slow to moderate eff.		
Compare Nogard "oil limestone" at 1260-1420 ft.		
Wyandotte, 1475-1510 ft.		
White dolomitic limestone (Guelph)	200	1100
900-950 "softer," is white, with moderate eff.		
950-1100 is very white, slow eff., the typical "Guelph," western Niagara or Manitoulin dolomite.		

STRASBURG OIL & GAS CO. WELL NO. 1.—Continued.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Compare: Monroe, 850-900 ft. Dundee, 1208-1343 ft. Nogard, 1420-1520 ft. Britton, 1550-1643 + ft. Riga, 1165-1275 ft. Wyandotte, to 1860 ft. Kalamazoo, 1730-1875 ft.		
Rochester shale? 1100-1140 "no sample saved." 1140-1170 "was broke or mud." 1170-1180 is impure mixed with greenish and rusty brownish fragments of limestone; eff. moderate to brisk, with marked iron stain. This is properly a part of the Clinton but seems to have some of the over-lying shale mixed with it, and an unconformity may well be suspected here.	70	1170
Compare: Monroe, 1110 ft. Wyandotte, 1870 ft. Swan, Grosse Isle well, 1400-1500?		
Clinton Ferruginous dolomite and limestone: Ferruginous dolomite 10 ft., 1180 ft. Described above. Swan, Grosse Isle at 1550 ft., is similar. 1180-1230, eff. slow to moderate; pink. 1230-1300, dark, moderate eff. 1300, white dolomitic limestone, brisk eff. No sample saved, was very red in color and soft shale. We call it 'red rock' in Ohio oil fields, always found just below Clinton lime.	130	1300
Clinton Iron Ore, Medina and Richmond Shales This band of red rock marks the base of the Silurian and the top of the Ordovician. As no sample has been preserved it is impossible, and probably would be so anyway to subdivide it, and it is a matter of taste whether it is to be reckoned with the one or the other. It may be correlated with— Monroe, 1110 ft. Dundee, 1563-1623 ft. Nogard, 1640 ft. Wyandotte, somewhere between 1890 and 2200 ft., probably about 2100 ft. Cheboygan, 2265-2407 ft.	40	1340
Lorraine or Mayaville shales 1340-1660 ft., all the same bluish slightly greenish shale, not eff.	320	1660
Utica (Eden) shales 1660-1700 ft., slight eff., dark shale. 1700-1800 ft., similar. 1800-1884 ft., no eff., yet darker bituminous shales. These Lorraine and Utica shales appear above the Trenton in all the wells cited below. Probably the lower part above is the typical Utica of most wells, i. e., Strasburg, 1880-1884 ft., with Pickford 475-525 ft.	224	1884
Trenton limestone 1884, "Top of Trenton rock; hard." Moderate eff. 1884-1890, "Top of Trenton rock; hard." Moderate to brisk eff. The dolomitization of the Trenton is confined to the very top. 1890-1937 ft., all effervesce freely and are a mixed pepper and salt in color. At 1937-1950 ft. is noted "a very light showing of oil and gas." The well was shot with 200 quarts of nitroglycerine. The top of the Trenton corresponds well with: Monroe, 1734 ft., with 80 ft. of black shale above. Dundee, 2133 ft., with 300? ft. of black shale above. Nogard, 2150 ft., with 200? ft. of black shale above. Wyandotte, 2610 ft. Note that it changes to limestone in about 10 feet also at Monroe, and the gas is a few feet down. The black shales also appear above, but the thickness assigned is very irregular.	105	1989

Note that it changes to limestone in about 10 feet, also at Monroe, and the gas is a few feet down. The black shales appear also above, but the thickness assigned is very irregular.

Dundee. At Dundee, in the western part of the county and in the old Macon or Christiancy, now Bullock, quarry are two other wells which reached the Trenton. The first was drilled in the quarry then owned by Mr. R. H. Nogard. Owing to the secrecy about the results, the citizens of Dundee inferred that success had been obtained and drilled another well the next year (1888) on the A. Wilkinson farm one mile south of the village. Both wells were failures. The Dundee well penetrated 144 feet of the Trenton formation and a little oil and gas were found, both of which "disappeared." The sandstone, possibly belonging to the Sylvania horizon, yielded some gas from 193 to 205 feet.

Comparing the record of the Potter well with that of the Dundee the top of the Trenton drops 483 feet in about 15 miles. This is equal to a dip of 32 feet per mile to the northwest.

NOGARD WELL.

Loc.: In the Nogard (Macon or Christiancy) quarry, N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, sec. 8, T. 6 S, R. 7 E.

Elevation 660 ft. A. T.	Thick- ness, feet.	Depth, feet.
Dundee and Monroe:		
Gray limestone.....	59	59
Monroe (including Salina) and Lower Dundee?		
Buff and white limestone.....	100	159
Blue limestone.....	150	309
Buff and blue limestone.....	260	569
Oil limestone.....	100	669
Buff limestone and brown marble.....	600	1269
Oil limestone.....	151	1420
Niagara:		
Snow white marble.....	100	1520
Red, white and blue marble.....	400	1920
Medina:		
Shale.....	30	1950
Utica:		
Gray, black and brown slate.....	200	2150
Trentone limestone:		

DUNDEE WELL.

Loc.: A. Wilkenson farm 1 mile south of village, N. E. $\frac{1}{4}$, N. E. $\frac{1}{4}$ sec. 25, T. 6 S. R. 6. E.

Elevation 680 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Quicksand.....	8	8
Clay.....	30	38
Dundee and Upper Monroe:		
Gray oil limestone.....	65	103
Upper Monroe or Detroit River Series:		
Sulphur limestone.....	70	173
Dark limestone.....	20	193
Fine gray sandstone, (Sylvania?) gas.....	12	205
Blue gray limestone.....	30	235
Sylvania:		
Gray sandstone.....	18	253
Fine limestone.....	105	358
Hard shell limestone.....	40	398
White sandstone.....	7	405
Lower Monroe or Bass Island Series:		
Dark limestone.....	48	453
Hard shell limestone.....	45	498
White putty limestone.....	70	568
White putty limestone, very hard.....	50	618
Buff limestone.....	220	838
Alternating blue, gray and brown limestone.....	315	1153
Fine buff limestone.....	10	1163
Gray limestone.....	7	1170
Buff limestone.....	23	1193
Niagara:		
Guelph dolomite—		
Light gray marble.....	15	1208
Snow white marble.....	135	1343
Lockport limestone:		
Dark blue marble.....	80	1423
Red marble.....	15	1438
Pinkish gray marble.....	35	1473
Rochester shale:		
Blue slate.....	30	1503
Clinton:		
Gray limestone (mineral water).....	60	1563
Medina:		
Red slate.....	60	1623
Lorraine (Hudson River) or Maysville:		
Gray slate.....	100	1723
Blue slate.....	110	1833
Utica shale:		
Brown slate.....	300	2133
Trenton limestone.....	144 +	2277

Milan. About 1900, a well 890 feet deep was drilled at Milan just a few rods south of the Washtenaw-Monroe county line. Later this well was deepened to 1643 feet, penetrating the Niagara. Water was struck at various horizons as in the Dundee, below 298 feet in the Upper Monroe, in the Sylvania below 535 feet, and in the Lower Monroe at 845 and 890 feet. Probably water was also struck in the top of the Upper Monroe.

MILAN WELL.

Loc.: At Milan a few rods south of the Washtenaw-Monroe county line. Depth, 1643 ft.

Elevation 685 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Clay, quicksand about 60 ft. and clay.....	130	130
Traverse:		
Cherty limestone.....	30	160
Blue shale.....	45	205
Blue shaly limestone.....	65	270
Limestone (fissure?).....	28	298
The top of the Dundee cannot be clearly made out owing to the caving. It is surely somewhere between 165 and 298 ft., more probably at or near the latter figure.		
Dundee:		
Limestone quite fine, H ₂ S water (brecciated and caving).....	97	395
Upper Monroe or Detroit River Series:		
Dolomite acicular, caving to 425 ft.....	30	425
Dolomite sandy.....	10	435
Dolomite with gypsum.....	20	455
Gypsum, mainly.....	80	535
Sylvania or Middle Monroe:		
Sandstones, pebbly at 820.....	288	823
Lower Monroe or Bass Island Series:		
Various veins of water, calcareous shale.....	7	830
Dark oily dolomite, more sulphuretted water.....	15	845
Cherty dolomite.....	45	890
Blue with mineralized water at 890 ft.		
With some black specks mixed.....	100	990
Blue clay shale.....	5	995
(Compare Britton 1015 ft.).		
Dolomite.....	30	1025
Salina?		
Anhydrite.....	75	1100
Dolomite.....	110	1210
Anhydrite.....	90	1300
Red, then blue shale.....	100?	1400
Brown, oily dolomite, fine, laminated.....	75	1475
Dolomite.....	65	1540
Rock salt.....	5	1545
Niagara?:		
Dolomite.....	98	1643

Newport. Northeast of Monroe, a well was drilled on the estate of C. H. Buhl, Berlin township. From samples taken every 20 feet, the following log was compiled.

NEWPORT WELL.

Loc.: N. E. $\frac{1}{4}$, S. W. $\frac{1}{4}$, sec. 1, T. 6 S., R. 9 E. Depth 910 ft.

Elevation 585± ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or Surface:		
Rusty pebbly clay	3	3
Lower Monroe. (Satina not separated off):		
Drab dolomite, considerable muddy residue. Fragments of calcite, and considerable anhydrite.	80	83
Light drab dolomite, with dark shaly fragments. Considerable muddy residue. Anhydrite and sand grains present.	10	93
Samples not saved.	72	165
Dark dolomite with carbonaceous flakes, which burn with flame. Brisk effervescence. Anhydrite and sand grains present.	30	195
Bluish-drab dolomite. Anhydrite is present. Flow of fresh water from 195 to 220 ft.	52	247
Samples wanting.	58	305
Bluish gray dolomite, carrying anhydrite and some selenite. Much muddy residue. Further flow of fresh water.	10	315
Bluish gray, argillaceous dolomite. Some anhydrite present throughout.	57	372
Buff dolomite with much yellow residue. The insoluble portion contains numerous rounded grains of quartz, some horn-blende and some black non-magnetic grains, which are probably some form of titanite iron oxide. Anhydrite.	48	420
Bluish dolomite. Drillings are coarse. Lumps of anhydrite with fragments of dolomite.	15	435
Quite similar to the bed 372 to 420 ft. Drillings are fine and looser as contrasted with the beds just above and just below. Much anhydrite is present.	13	448
Practically identical with bed 420 to 435 ft. A bluish dolomite, drillings coarse. Anhydrite present in lumps.	19	467
Bluish, dolomitic shale. Slow eff. Much bluish, muddy sediment. Some anhydrite.	33	500
Bluish drab, argillaceous dolomite. Lumps of anhydrite and black flakes.	20	520
Bluish, dolomitic shale, essentially similar to that occurring from 467 to 500 ft. Fragments of anhydrite with shale.	40	560
Blue and drab dolomite. Drillings fine. Fragments of anhydrite.	38	598
Drab to gray dolomite. Anhydrite and some sand grains. Lower portion of bed is more impure.	17	615
Drab to gray dolomite, with varying amounts of anhydrite.	105	720
The fine samples from this bed are all alike and more buffish than those from above bed. The rock is a dolomite also, containing seams of carbonaceous matter, fragments of anhydrite and scales of selenite. For some reason, the rusty iron grains are exceedingly abundant in all samples. (Rusted fragments of steel from drill?)	95	815
Drillings have a gray color and under the magnifier look much like pure anhydrite. Slow eff. The rusty grains are not quite so abundant, but are numerous.	10	825
The drillings from this bed are a purer white than above. Little eff. Much anhydrite.	8	833
Gray to drab dolomite with fragments of anhydrite and scales of selenite.	11	844
Samples missing.	16	860
Bluish gray dolomite. Drillings relatively coarse containing bluish flakes and fragments of anhydrite.	50	910

Ida. In 1893, a deep well was drilled at Ida from which a more complete record was obtained than from the Potter well. This is located on the Simeon Van Akin property, N. E. $\frac{1}{4}$ of N. E. $\frac{1}{4}$, sec. 3 of Ida township. The altitude of the well is about 640 feet A. T. A pipe was driven 22 feet into the rock before drilling began. Ten feet of "common limerock" was found to overlie 45 feet of Sylvania

sandstone. Gray limestone (dolomite) followed to 320 feet where a light blue shale was struck. After going through this shale a darker limestone than the overlying beds was entered and at about 480 feet gas was struck in considerable quantity, the flow increasing for the next 60 feet. At 700 feet, 100 feet of "light colored rock" was struck. The drilling reached a depth of 1200 feet when work was suddenly stopped.

Riga. About 1899, a well 1700 feet in depth was sunk at Riga, Monroe county, but owing to disputes and legal troubles very little was learned of the record. Dr. Lane examined some of the samples from 1165 to 1275 feet and thought that they appeared to be the white dolomites of the Upper Niagara. Judging from other drillings in the county, it is about the depth at which it should occur.

South Rockwood. There are several other deep wells in the county of which no log, or at best only a part of a record has been obtained. Near South Rockwood the Frey well, N. E. $\frac{1}{4}$ of N. E. $\frac{1}{4}$, sec. 33, T. 5 S., R. 10 E., is said to have penetrated 12 feet of salt at about 1200 feet. No mention is made of the occurrence of oil and gas. About 1903 another well, the Lennard, 2430 feet deep was drilled near the swinging bridge over Huron river. The record is very poor and the "sand" in the record may mean only granular limestone or dolomite.

LENNARD WELL.

Loc.: Near swinging bridge over Huron river, South Rockwood.

	Thick- ness, feet.	Depth, feet.
Surface.....	30	30
Sylvania?:		
White sand.....	30	60
Black.....	30	90
Record missing from 90-950 feet,		
Sand.....	100	1050
Lime.....	80	1130
Sand.....	155	1285
Clinton?		
Red rock (Cf. Strasburg 1300-1340 ft. or 1140-1170, which is 584 ft. above Trenton.).....	10	1295
Lorraine and Utica:		
Slate.....	45	1340
Sand, water.....	65	1405
Shale.....		2045
Dark at bottom. Smell.		
Trenton at 2430 ft.		

LENAWEE COUNTY.

The belt of rocks over which surface signs are most abundant in southeastern Michigan crosses the northwestern part of Monroe into Lenawee county and consequently exploration has extended westward into the latter county. There are a number of deep wells in this

county, chiefly in the eastern half as at Britton, Blissfield, Adrian and Clinton.

Adrian. At Adrian a well 1650 feet in depth was drilled by the Adrian Gas Co. It probably reached the top of the Salina, but does not appear to have encountered any marked signs of either oil or gas. The Berea was present as a gray sandstone and the Antrim as a brown shale. Inasmuch as drillers make no distinction between limestone and dolomite the Dundee cannot be separated in the record. Water or brine was probably struck in the Berea, though not noted in the records; mineral water was encountered at 805 feet, sulphur water at about 940 feet, brine in the Upper Monroe at about 1135 feet, and more brine in the Lower Monroe at 1520 feet.

ADRIAN GAS CO. WELL.

Loc.: Adrian. No samples.

Elevation 810 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface.....	20	20
Quicksand.....	18	38
Gravel.....	60	98
Gravel and quicksand.....	82	180
Coldwater shales:		
Sandstone, light gray.....	4	184
Soft white "slate" or sandstone.....	330	514
Sunbury (Berea):		
Brown "slate" (shale).....	40	554
Berea:		
Gray sandstone.....	30	584
Antrim:		
Brown "slate".....	80	664
Brown shale.....	141	805
Traverse (Hamilton) Formation:		
Mineral water at 805 ft.		
Reddish hard limestone. (Mouth of driving pipe 180 ft.; casing to 500, then the second time to 885 ft.).....	80	885
Black slate or shale. Regular limestone at 900 ft.....	15	900
Dundee (Corniferous) and Monroe:		
Limestone, hard, dark drab to gray.....	750	1650 +
Sulphur water at 940, brine at 1135 and 1520 ft.		
Lorraine:		
Slate rock, white and soft (or anhydrite?)		

Britton. The Britton well, 1700 feet in depth, was drilled about 1900. At 1400 feet and at 1500 feet brown oily dolomites were struck as in many other wells in southeastern Michigan, but no showing of oil was observed.

On the lot of John Wiggin in Britton near the above well, a shallow one 90 feet deep was put down for water and a pocket of gas was struck, the glow of which, when lighted, could be seen in Tecumseh about six miles away. The original pressure increased from 35 to 41 pounds, which would be about equal to the hydrostatic head.

BRITTON WELL.

Elevation 705 ft. A. T. (Approx.)	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface clay and gravel.....	93	93
Antrim shale:		
Black shales.....	67	160
Pyritiferous gray shale.....	15	175
Pyritiferous black shale.....	35	210
Traverse Group:		
Cherty dolomite.....	25	235
Green shale.....	30	265
Cherty dolomite.....	40	305
Blue calcareous shale.....	95	400
Dundee (Corniferous, Onondaga) limestone:		
White or brownish crinoidal limestone with water and traces of oil and gas.....	100	500
Upper Monroe or Detroit River series:		
Gypsiferous dolomite.....	75	575
Gypsum (Anhydrite).....	50	625
Dolomite.....	50	675
Dolomitic limestone.....	33	708
Dark cherty dolomite.....	37	745
The same, bluer.....	5	750
Sylvania:		
Dolomitic sandstone.....	25	775
Gypsiferous dolomites.....	50	825
The same with a little chert and sand.....	75	900
Dolomitic sandstone, salt water.....	100	1000
Shale.....	15	1015
Casing to 1012 or 1015 ft.		
Dolomite, dark blue at 1180 ft.....	485	1500
Rope black, and H ₂ S at 1200, where there is a slow very salt seepage. There was said to be 30 ft. of brown oily dolomite at 1400 ft.?		
Dark brown oily dolomite.....	50	1550
Niagara:		
Light white sugary dolomite, typical Guelph.....	84	1634
Mineral water at 1600 ft.		

Blissfield. The Blissfield well, one of the deepest in the southeastern district, penetrated the Trenton, but unfortunately only a meager record from memory could be obtained.

BLISSFIELD WELL.

Loc.: Sec. 30, T. 7 S., R. 5 E.

	Thick- ness, feet.	Depth, feet.
Drift.....	100	100
Gravel; water rose and filled first 8 inch casing.....	20	120
First limestone about [to ? dark slate and black water].....	300	420
Water in limerock at 1600 ft.		
Struck Trenton at 2342 ft.		
Trenton rock.....	60	2402

Manchester. Six miles southeast of Manchester a well was drilled about 1904 by the Manchester Oil Co. It is said to have reached only a depth of 690 feet and appears to have stopped in the Traverse shales. There is some doubt as to the exact correlations, but the record as made from well samples by the U. S. Geological Survey is given below.

MANCHESTER WELL.

(U. S. Geological Survey Well No. 25).

Loc.: Six miles southeast of Manchester, Washtenaw county. Manchester Oil Co., owners.
C. A. Elliot, driller.

Elevation about 830 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	174	174
Coldwater:		
Blue shale.....	153	327
Berea:		
Horizon of Berea? Red shale.....	2	329
This red shale clay might represent a weathered surface, or some other zone of special oxidation. The banding upon it is quite distinct. Compare Bedford shales. Compare Hillsdale at 1030-1033, Osseo 800, Adrian, 514.		
Antrim:		
Usual shale.....	12	341
Black shale. This looks very much like the Ohio black shale, and would seem to indicate that the horizon of the Berea here is at 327-329.....	11	352
Bluish shale.....	48	400
Blue shale.....	90	490
Brown shale.....	110	600
Compare Hillsdale 1350, Osseo 1145-1214, Adrian 805, Madison Oil and Gas Co. 665.		
Traverse (Hamilton):		
Gray shale; non-eff.....	60	660
Gray shale; slightly eff.....	30	690

"The samples from 600 feet down might quite likely be Traverse or they might be a gray streak in the Antrim. From 327 feet down to 600 feet, or thereabouts, should be Antrim."—Lane.

According to Lane, this well is near and perhaps the same well as that of U. Arnold about two miles from Clinton, sec. 2, T. 4 S., R. 3 E. In the Arnold well, brine was reported at about 1000 feet.

Madison Township. In 1905 the Madison Oil & Gas Co. drilled a well 764 feet in depth on the Snedeker farm, N. E. $\frac{1}{4}$ of sec. 15, T. 7 S., R. 3 E. From the character of the water near the bottom of the well Dr. Lane believes that it did not reach the Dundee oil horizon. Water was struck in the black shales of the Antrim from 612 to 618 feet. At this horizon there was a trace of gas also. To have reached the Trenton the well very probably would have had to go 2000 feet below the base of the Antrim.

MADISON OIL AND GAS COMPANY WELL.

Loc.: N. E. $\frac{1}{4}$ of sec. 15, T. 7 S., R. 3 E.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	20	20
Clay and sand.....	60	80
"Sand and gravel, dark and light".....	115	195
Coldwater:		
Shale, with shaly till? "clay and gravel, dark".....	55	250
Blue and light shale, with occasional calcareous streaks.....	165	415
Gritty shale.....	15	430
Sunbury shale:		
Black shale.....	20	450
Berea grit:		
Very fine grained sharp white sandstone or flagstone, salty.....	50	500
Antrim:		
Bituminous black shale with pyrite.....	112	612
At 612 to 618 ft. main water, with a trace of illuminating gas. About 14 per cent salts, sulphates low.		
Sandy black shale.....	53	665
Brown limestone (oily).....	15	680
Dark or black shale.....	20	700
Traverse:		
Brown dolomitic limestone, with white chert.....	64	764

"The beds in which the well closes are probably not much above those in which is the top of the Wyandotte well, which struck Trenton rock at 2610 feet. The limestone at 665 or 700 feet probably corresponds to that at 420 feet in the Blissfield well, which reached the Trenton at 2342 feet; and to that at 350 to 385 feet beneath South Bend, where the Trenton was reached at 1585 feet. The salt beds along Detroit River thin rapidly to the south and west, but at Adrian from the Devonian black shale or Antrim down to the Trenton is probably not less than 2000 feet. In view of the dolomitic character of the limestone, the strength of the water and its relative freedom from

sulphur I do not think this well has yet reached the Dundee, the oil bearing horizon of Port Huron and Canada around Petrolia. Two hundred feet more should go well into it."—Lane.

HILLSDALE COUNTY.

Hillsdale. Several deep wells have been drilled in Hillsdale county. At Hillsdale two were bored in the courthouse square, respectively 1350 and 1550 feet in depth. The log of the deeper well, given below is a very poor record compiled from hearsay accounts.

HILLSDALE WELL.

	Thick- ness, feet.	Depth, feet.
Drift.....	?	?
Soft laminated micaceous sandrock.....	?	20
Mainly bluish shales with arenaceous seams and harder, probably calcareous ledges. The color of the shales became dark, bituminous, in the lower part (Sunbury?).....	1100	1120
Hard red rock with much iron pyrite, and strongly saline water.....	230?	1350?
Fifty feet of white limestone.....	50?	1400?
Soft calcareous rock to end.....	150?	1550

Osseo. At Osseo, C. M. DeWitt drilled a well 1430 feet in depth. According to Mr. DeWitt, gas and oil were struck just below black and brown shales (Antrim) from 1219 to 1259 feet, gas again at 1380 feet and oil and gas below 1400 feet. The "big flow" of gas came at 1400 feet, and the oil just below 1420 feet. The first oil and gas horizon appears to be in the top of the Traverse, while the lower one is quite probably in the Dundee. An *Atrypa reticularis* from the oil horizon, indicates that it was probab'y that of the "bastard Trenton" or Dundee, and certainly not that of the Trenton proper.

The well was filled for about 150 feet with stone and cement and the gas rock above was shot. The gas, originally having a pressure of about 70 pounds, was nearly sufficient to fire the 25 H. P. engine used in pumping the mineral water which was struck in abundance below 1229 feet. The pressure has since decreased to about 38 pounds. According to Mr. DeWitt, the cement filling in the bottom of the well did not set, or only partially, so that a heavy lubricating oil can be obtained after the 1100 foot head of water is pumped off.

OSSEO WELL.

C. M. DeWitt, owner. Lige Curry, driller, Bradner, Ohio.

(Record from a few samples and data furnished by C. M. DeWitt.)

Elevation about 1065 ft. A. T.	Thick- ness, feet.	Depth, feet.
Drift.....	214	214
Coldwater shale:		
Blue shales.....	700	914
Berea? (Apparently horizon absent or not recognized.)		
Antrim shale:		
Brown or black shales.....	231	1145
Stray "oil sand".....	5	1150
Black shale, pyritic, odor of petroleum.....	64	1214
Traverse (Hamilton) Formation:		
Pepper and salt.....	5	1219
Dark brown rock, gas.....	5	1224
Lighter brown rock, more gas.....	5	1229
Lighter rock. Some oil and more gas. 100 ft. of salt water in well.....	30	1259
Lighter rock. Water rock very light or hard salt "sand." 400 ft. of mineral water in well.....	20	1279
Very light hard rock or "salt sand." Fine drilling.....	25	1304
Light rock becoming darker with bluish cast (shaly?).....	21	1325
Rock of a bluish cast (shaly?).....	25	1350
More salt water bearing rock.....	30	1380
Dundee:?		
Brown rock. Heavy flow of water and gas. Water rose to within 330 ft. of the surface.....	20	1400
The "Trenton" (Dundee limestone) with showing of oil and big flow of gas.....	20	1420
Light brown rock of yellowish cast. Pebble oil rock, very porous.....	10	1430
Well afterwards filled in with cement and stone for 150 ft. and gas rock shot. "Lots of oil if head of water is pumped off." Gas pressure originally 70 pounds.		

The exact top of the Dundee is not certain from the above record, but it is probably between 1380 and 1400 feet. From this, the dip north-northeast to Jackson would be about 20 feet per mile. Making the comparison for the base of the Antrim in the two wells, the dip is a little over 22 feet per mile.

WAYNE COUNTY.

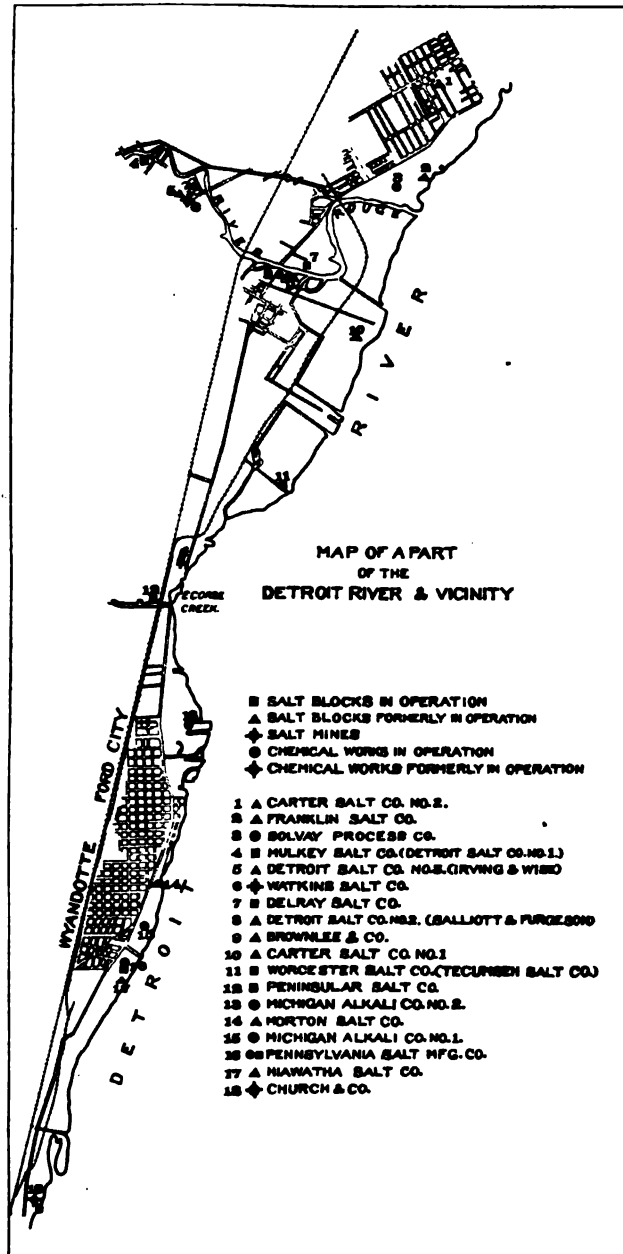


Figure 9. Map showing the location of salt blocks and salt wells in Wayne county (after C. W. Cook).

Trenton. In Wayne county, wells are very numerous, especially along Detroit river where many have been put down for salt (Fig. 9). At Trenton there are six wells of which the record of No. 5 of Church & Company is given below. The well yielded an odor of gas at the bottom.

CHURCH & CO. WELL NO. 5.

Loc.: Church & Co. plant, Trenton.

Elevation about 580 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	75	75
Dundee and Upper Monroe undivided:		
Limestone; moderate to brisk eff.....	65	140
Limestone; fairly brisk eff.; darker and coarser splinters than beds below; Allegan well 1280+ and St. Clair River 520 ft. resemble the top of the Trenton; light brown limestone.....	10	150
Limestone fine grained and light buff, moderate to brisk eff.....	40	190
Samples missing, doubtless limestone.....	30	210
Genuine limestone, very brisk eff., Amherstburg, Anderson quarries.....	10	220
Dark brown limestone, moderate to very brisk eff.....	20	240
Limestone and dolomite.....	10	250
Sample missing, probably limestone or dolomite.....	10	260
Limestone and dolomite with bluish tinge.....	10	270
Dolomite.....	10	280
Sylvania or Middle Monroe:		
Fine grained white sandstone.....	120	400
Dolomite with chert.....	10	410
Fine white sandstone with white chert.....	10	420
Sample missing.....	10	430
Very calcareous sandstone.....	10	440
Pure white sandstone.....	10	450
Sandy limestone or dolomite.....	10	460
Pure white sandstone; water.....	10	470
Dolomitic sandstone.....	10	480
Lower Monroe:		
Dolomite with scarcely any sand.....	10	490
Dolomite, moderate eff. at top, slower toward bottom.....	110	600
Very fine grained calcareous marl, fairly rapid eff.....	10	610
Dolomite, with little or no gypsum.....	60	670
Much white chert with shaly streaks down to 660 ft.....		
Dolomite and anhydrite.....	60	730
Mainly dolomite and anhydrite.....	70	800
Moderate eff. in places. Dark bluish shales.....	10	810
Compare Wyandotte at 800-860 ft., Ford No. 23, 700-735 ft.....		
Gypsiferous dolomite passing into bluish gypsiferous shales.....	30	840
Anhydrite with fragments of green shale.....	30	870
Salina:		
Nearly pure gypsum.....	20	890
Cream colored dolomite, gypsiferous.....	40	930
Buff dolomite.....	20	950
Dark shale.....	10	960
Blue light yellow and buff dolomite.....	20	980
Brown dolomite and blue, green and gray shale.....	10	990
Dark bluish gray shale with buff dolomite and bluish gray gypsiferous beds.....	10	1000
Bluish shale, gypsiferous at times.....	170	1170
Light buff or cream colored dolomite.....	20	1190
Largely bluish shales, gypsiferous.....	50	1240
Dark dolomitic shales, dolomite, anhydrite at 1280 ft. and bluish to brown dolomites below.....	50	1290
Buff dolomites.....	80	1370
Smell of gas at 1310 and 1340 ft.		

No rock salt was struck in this well, but, in the other Church & Co. wells located 200 to 300 feet north, a single bed, varying in the dif-

ferent wells from 5 to 33 feet in thickness, was penetrated. This well indicates the exact southern limit of the salt beds.

Grosse Isle. Judge James Swan in 1903-04 drilled a deep well¹ for oil or gas in the southwestern part of Grosse Isle just opposite Snake Isle and about three quarters of a mile from the extreme southern point of the island. No oil or gas in any noteworthy amount was struck, though the well reached a depth of 2375 feet. Enormous flows of water were struck at various depths. The first considerable flow was at 420 feet, and the second at 450 feet was much larger. Both were fresh though the water had an odor of "sulphur" probably from sulphur dioxide gas. The deeper flows were much smaller and sulphuretted. The water, which is potable, at first escaped from the 13 inch casing to the enormous quantity of 4,320,000 gallons in 24 hours—enough to supply the whole water front from Detroit to Lake Erie several times over.

A partial record of this well was obtained by Mr. Forest H. Brown for the Michigan Geological Survey in July 1903, when it was about 785 feet deep. According to the record then obtained, the well had penetrated 14 feet of clay, 300 feet of "limestone" and 70 feet of "sand." The latter is the Sylvania. This would give an elevation of 268 feet above tide for the top of this formation, the mouth of the well being about 580 feet A. T. Across Detroit river at Elliot's Point, Ontario, the Sylvania is struck at a depth of 69 feet and on the farm just north of the Point at 42 feet. This indicates that the Sylvania dips sharply to the northwest, the dip being over 60 feet per mile. It must be remembered, however, that this formation is very variable in thickness within short distances, hence abnormal dips may be due merely to local thickening or thinning.

Romulus Township. In 1903, a well 1820 feet deep was drilled by Newell for Laurence and Griffith on the Emil Twark farm, section 12, Romulus township.

¹W. H. Sherzer, *Geology of Wayne County*, Pub. 12, Geol. Surv. 9, 1911, p. 249.

E. TWARK WELL.

Loc.: Emil Twark farm, S. E. $\frac{1}{4}$ of N. W. $\frac{1}{4}$, sec. 12, Romulus Twp.

Elevation 620 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Drift	92	92
Gravel	3	95
Lime	21	116
Gray limestone	25	141
Bell (Marcellus) shale:		
Coal (black bituminous shale probably)	2	143
Black slate	7	150
White lime	7	157
Black slate	15	172
Black shale	10	182
Dundee (Corniferous) limestone:		
Lime	63	245
Black shale	5	250
Lime	36	286
Black lime	12	298
Upper Monroe or Detroit River Series:		
Gray lime	24	322
White lime	63	385
Sylvania (Middle Monroe):		
White sand	5	390
Black slate	8	398
White sand	65	463
Sand rock	22	485
White lime	15	500
Sand rock	45	545
Lower Monroe or Bass Island Series:		
White lime	240	785
Blue lime	10	795
White lime	75	870
Brown shale	12	882
White lime	43	925
Salina:		
Salt rock	35	960
White lime	25	985
Brown shale	15	1000
Salt rock	46	1046
Slate	7	1053
Salt rock	34	1087
White lime	30	1117
Salt rock	25	1142
White lime	32	1174
Fine white salt	24	1198
Lime	7	1205
Salt rock	53	1258
Lime	5	1263
White lime	7	1270
Salt	20	1290
Lime	25	1315
Shells and slate	62	1373
Lime	26	1398
Salt rock	27	1423
Shells and slate	30	1453
White lime	23	1476
Salt rock	45	1521
Slate	20	1541
Salt rock	27	1568
White lime	15	1583
Salt rock	20	1603
Lime	20	1820

Wyandotte. Many years ago a well was drilled at Wyandotte to the Trenton, which was reached at 2610 feet. According to A. C. Lane, the record is that of the driller and is apparently not very trustworthy. Notes in parenthesis are by Lane and A. Winchell.

WYANDOTTE WELL.

Lancy and Churchill, contractors. Record from C. E. Wright and A. Winchell. Driller's record.

Elevation 580 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Clay and gravel	75	75
Dundee (Corniferous):		
Dark limestone	15	90
Light brown limestone	10	100
Gray limestone	25	125
Upper Monroe or Detroit River Series:		
Brown sand with "slate"	30	155
Brown sand and lime	5	160
Brown and white limestone	70	230
Sylvania (Middle Monroe):		
Free-stone	60	290
Lower Monroe or Bass Island Series:		
White and brown limestone (white and black sand. W.)	70	360
Gray limestone	5	365
Shelly limestone	30	395
Brown limestone	5	400
Muddy limestone	30	430
Very dark limestone, struck sulphur water	104	534
Limestone and "slate"	66	600
Slate and soapstone (caved to this point. W.)	15	615
Limestone and "slate" (? how far gypsum. L.)	75	690
White limestone and slate	40	750
Salina:		
White lime and salt mixed	70	800
Pure white salt	30	830
Salt and lime, shelly	40	870
Light brown limestone	30	900
Light brown shaly limestone	20	920
Dark brown shaly limestone	20	940
Pure salt	15	955
Sand and lime	5	960
Pure salt	5	965
Salt and lime shell	5	970
Lime and "slate," shaly	75	1045
Pure limestone	10	1055
Slate and brown limestone	5	1060
Pure brown limestone	20	1080
Pure brown salt	10	1090
Pure white salt	100	1190
Salt and brown limestone	45	1235
Dark shaly limestone	5	1240
Dark limestone	90	1330
Very dark limestone	5	1335
Brown limestone	5	1340
Blue limestone	10	1350
Brown limestone	10	1360
Brown limestone, very hard	5	1365
Hard dark limestone	5	1370
Brown and blue limestone	5	1375
White and blue limestone mixed	50	1425
White crystalline limestone	15	1440
Brown and white limestone. Water	35	1475
Fine brown limestone. Gas	25	1500
Fine brown limestone	10	1510
Niagara at 1510 ft., Guelph and Lockport:		
Limestone (dolomite)	350	1860
Rochester:		
Slate (shale)	10	1870
Clinton:		
Limestone	20	1890
Red rock (red shale or clay) Medina?	110	2000
Medina, Richmond:		
Black slate	20	2020
Red rock (red shales)	80	2100
Slate	95	2195
Red rock (red shales)	5	2200
Lorraine:		
Gray sand	10	2210
Slate (shale)	40	2250
Dark grayish shale: no eff.	250	2500
Trenton at		2610

The Morton Salt Co. of Wyandotte drilled a well a few years ago to the bottom of the "Big Salt." A very complete set of samples was obtained from which the following record was compiled by Dr. Lane. The first salt was struck at 730 feet and the Sylvania at 197 feet, or about 40 feet higher than at Trenton, indicating a low arch in the vicinity of Wyandotte.

MORTON SALT CO. WELL.

Elevation 574 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Muck, thin clay. Surface deposits.	62	62
Upper Monroe or Detroit River Series:		
Light buff dolomites at 10 ft., perhaps oolitic.	75	137
At 82 to 92 ft. rather brisk eff., generally moderate to slow, some rounded sand grains.		
Dolomites dark brown, bituminous, with sulphur and sometimes pyrites, with moderate eff. Compare Church No. 5 down to 290 ft.	60	197
Sylvania (Middle Monroe)	65	262
Quartz sand, clear, very fine, most of the grains from .5 to .2 mm., rounded down to some where between .1 and .25mm. Compare Ford 23, 235-325; Mt. Clemens, 965.		
Dolomite, light, eff. moderate, in specks (due to crystals perhaps). Compare Ford 23, 325-340.	20	282
Silicious dolomite.	35	317
Dark brown, with red, rusty quartz sand and pyrites in spots, and very cherty at the base. Compare Ford No. 23, 375-435.		
White sand like that above.	35	352
Sandy dolomite.	10	362
Grains rounded down to .16 mm.		
Lower Monroe or Bass Island Series:		362
Cherty dolomite.	50	412
Dolomite, dove colored, with relatively little chert.	20	432
Dolomite.	30	462
Bluish, buff, massive.		
Coarse chips at 337-447. Compare Edison 462-377.		
Brown dolomite.	15	477
Light dolomite.	15	492
Dark dolomite.	35	527
Light dolomite.	25	552
Stylolitic with black specks.		
Impure gypsum.	45	597
Bluish, with some dolomite and nearly pure at 587 ft.		
Compare Edison, Fort Wayne, 900-950, especially 925 with 587.		
Compare Church No. 2 at 720 ft.		
Anhydrite is quite abundant at 627 ft.		
Compare Edison, Fort Wayne, 1000 ft.		
Dolomite.	20	617
Oolitic at 602 ft.		
Bluish dolomite and anhydrite.	113	730
Salina:		
Salt and dolomite.	60	792
At 730 ft. is the first salt. The Edison Fort Wayne well seems to have salt at higher levels, the first salt there at 1010 ft., belonging to the upper part of this group apparently. Compare Church No. 5 at 890 ft.		
Eureka, Wyandotte, 730-800.		
Ford No. 1, 830.		
Solvay No. 13, 880.		
Solvay No. 16, 890.		
Romulus, 925.		
Tecumseh Salt Co., 828.		
River Rouge Imp. Co., 815.		
River Rouge Salt Co., 871.		
Detroit Salt Co., 906.		
Stroh Brewery, 1150.		
Royal Oak, 1543.		
New Baltimore, 1600.		
Saint Clair, 1600.		
Marine City, 1604.		
Port Huron, 1500.		

MORTON SALT CO. WELL—Concluded.

Elevation 574 ft. A. T.	Thick- ness, feet.	Depth, feet.
Salt.....	50	842
Dolomite, hard.....	80	922
Compare Wyandotte 870-900 ft.		
Dolomite with anhydrite.....	10	932
Anhydrite with salt.....	10	942
While this is the second salt in this well, and would thus correspond to 940 ft. at Wyandotte, Eureka well, and 852 ft. at Ford No. 23 (probably really to 1027 ft.) it is probable that these salt beds are not persistent. Edison, Fort Wayne, 1280-1292 ft., may also correspond. Ford No. 1 is the same.		
Dolomite.....	5	947
This is merely a parting, but seems fairly persistent. Compare Ford No. 1, 968-976; Wyandotte, 960.		
Salt.....	15	962
Dolomite, anhydrite and clay.....	100	1062
Almost solid anhydrite.....	5	1067
Compare:		
Edison, Ft. Wayne, 1400 ft.		
Wyandotte, 1045.		
Dolomite and anhydrite.....	50	1117
The base of this is the top of the main and, it seems to me, the most persistent salt bed. We should then compare:		
Church No. 6, Trenton, 1280.		
Wyandotte Eureka, 1080-1235 (less 45 ft.)		
Morton, 1119-1323.		
Romulus, 1475-1600 with partings.		
Milan, 1540-1545.		
Zug Island, 1290-1528.		
Solvay No. 11, 1370-1602 with parting.		
Edison, Ft. Wayne, 1445-1636.		
Stroh, 1565-1815.		
Royal Oak, 2115-2475.		
Port Huron, 1991-2190.		
Salt, dolomite and anhydrite mixed.....	5	1122
Salt, samples to 1137 ft.....	201	1323

Many other wells have been drilled at Wyandotte for salt, of which the Michigan Alkali Company have about twenty-five. The record of one of these wells (known as the Ford wells) shows five salt horizons, the first salt coming in at about 830 feet.

J. B. FORD No. 1 WELL.

Loc.: Michigan Alkali Co. Plant, Wyandotte.

Elevation about 580 A. T.	Thick- ness, feet.	Depth, feet.
Surface, clays, etc.....	63	63
Upper Monroe:		
Limestone.....	199	262
Sylvania sandstone.....	110	372
Lower Monroe:		
Limestone (dolomite).....	458	830
Salina:		
Salt.....	46	876
Limestone (dolomite).....	92	968
Salt.....	8	976
Limestone (dolomite).....	8	984
Salt.....	9	993
Limestone (dolomite).....	133	1126
Salt.....	87	1213
Limestone (dolomite).....	10	1223
Salt at.....		1300

Delray. In Delray, the Solvay Process Co. have a large number of wells down to the Salina for salt, which, in the vicinity of their Delray plant, is struck from 865 to 890 feet. No noteworthy amounts of oil or gas were struck in any of the drillings. The Niagara is apparently over 1600 feet deep. The "Big Salt" is near the bottom in all of the wells, but according to Sherzer, this bed in the Eureka Iron Company's well is underlain by over 300 feet of dolomite, hence it is near the middle of the Salina. In such case, all of the wells in the vicinity of Detroit represent only partial sections of the Salina. The records of only three of the wells are given below. The others are very similar.

The Sylvania sandstone was reached at 415 feet, considerably deeper than in River Rouge and Wyandotte.

SOLVAY PROCESS COMPANY WELL, NO. 13.

Loc.: Near Delray plant.

Elevation about 575 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Alluvium (clay, sand, etc.).....	86	86
10-in. casing.....		
Dundee and Upper Monroe or Detroit River Series:		
Limestone.....	64	150
Slight flow of sulphur water.....		
Limestone.....	150	300
Large flow of sulphur water.....		
Limestone.....	51	351
8-in. casing.....		
Limestone.....	71	422
Large flow of water.....		
Sylvania (Middle Monroe):		
Sandstone.....	90	512
Lower Monroe or Bass Island Series:		
Very hard limestone.....	368	880
Salina:		
Salt.....	40	920
Limestone.....	5	925
Salt.....	5	930
Limestone.....	15	945
Salt.....	30	975
Limestone.....	5	980
Salt.....	25	1005
Limestone.....	25	1030
Salt.....	25	1055
Limestone.....	15	1070
Salt.....	65	1135
Limestone.....	37	1172
6-in. casing.....		
Limestone.....	53	1215
Salt.....	10	1225
Limestone.....	140	1365
Salt.....	120	1485
Limestone.....	10	1495
Salt.....	105	1600
3-in. casing.....		
*Limestone.....	3	1603
Bottom of well.....		

*All of the "limestone" in the Lower Monroe and most of it in the Upper Monroe is probably dolomite.

SOLVAY PROCESS COMPANY WELL, NO. 16.

Elevation about 575 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Alluvium (clay, sand, etc.)	87	87
Bottom 10-in. casing.		
Dundee and Upper Monroe or Detroit River Series:		
Limestone.	38	125
Slight flow of sulphur water.		
Limestone.	100	225
Increased flow of sulphur water.		
Limestone.	100	325
Large flow of sulphur water.		
Limestone.	30	355
Bottom 8-in. casing.		
Limestone.	75	430
Sylvanian or Middle Monroe:		
Sandstone.	60	490
Hard limestone.	35	525
Sandstone.	15	540
Lower Monroe or Bass Island Series:		
Very hard limestone.	20	560
Limestone.	330	890
Salina:		
Salt.	43	933
Limestone.	6	939
Salt.	12	951
Limestone.	19	970
Salt.	28	998
Limestone.	7	1005
Salt.	25	1030
Limestone.	35	1065
Salt.	35	1100
Limestone.	20	1120
Salt.	30	1150
Limestone.	19	1169
Bottom 6-in. casing.		
Limestone.	76	1245
Salt.	12	1257
Limestone.	5	1262
Salt.	5	1267
Limestone.	138	1405
Salt.	203	1608
Limestone.	4	1612
Salt.	6	1618
Bottom 3-in. casing.		
Salt, bottom of well.	7	1625
Well commenced flowing Aug. 6, 1906.		

ZUG ISLAND WELL.

Elevation about 575 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Clays and surface earth.....	73	73
Dundee and Upper Monroe or Detroit River Series:		
Dolomite?	52	125
Shale.....	35	160
Dolomite?	60	220
Sylvania (Middle Monroe):		
Sandstone, 94 per cent SiO ₂	22	342
Sandy lime.....	88	430
Lower Monroe or Bass Island Series:		
Soapstone (Calcareous shale?).....	125	555
Brown lime.....	30	585
Gray lime.....	55	640
Lime.....	35	775
Limestone.....	25	800
Saltina:		
Salt.....	40	840
Mixed lime.....	32	872
Salt.....	56	928
Lime.....	27	955
Salt.....	20	975
Lime.....	10	985
Salt.....	55	1040
Lime.....	88	1128
Salt.....	16	1144
Lime.....	6	1150
Salt.....	15	1165
Lime.....	25	1190
Shales.....	17	1207
Slate.....	83	1290
Salt.....	228	1528

River Rouge. In the River Rouge, but at some distance toward Wyandotte, the River Rouge Improvement Company drilled a well for the United Alkali Company, striking salt at 815 feet. Near the River Rouge, Mr. Dalton put down wells for the Tecumseh Salt Company, in which the Sylvania sandstone was struck from 365 to 492 feet and yielded heavy flows of sulphuretted water. In a well at Brownlee & Company's sawmill (578± feet A. T.), Ecorse, the salt was struck at 875 feet and the Sylvania at 395 feet.

Oakwood. One of the most important records showing the exact nature of the rock formations, their thickness and the water horizons, is that obtained from the Oakwood salt shaft near Detroit. The first attempt⁴ to sink a shaft for mining rock salt was made in 1902, but this was a failure owing to the collapse of the brick drop casing. The second attempt was successful only after the greatest difficulty in overcoming suffocating gases and floods of water. When the shaft was 420 feet in depth Mr. E. Bradt, the engineer, estimated that the total flow into the shaft was 2,000,000 gallons per minute. The Dundee limestone yielded so much hydrogen sulphide gas that the workmen were overcome or their eyes painfully affected. Operations were stopped for some months from this difficulty.

⁴Sherzer: Geology of Wayne county, Pub. 12, Geol. Ser. 9, 1911, pp. 279-280.

Strong flows of water were struck at six different horizons, viz.: In the drift, just over the bed rock, in the Dundee, and in the Upper Monroe. There was also a seepage flow in the Sylvania. The great flow of water from a 5 foot horizontal opening was finally shut off by forcing in a slush of concrete cement under a pressure of 1200 pounds per square inch. No gas outside of the H₂S gas was observed at any of the horizons, but asphaltum streaks occurred in the Lucas dolomites of the Upper Monroe.

SECTION OF OAKWOOD SALT SHAFT.

Loc.: One-half mile south of the River Rouge in Oakwood, a small suburb of Detroit.

Elevation of mouth of the shaft, 575.2 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface deposits:		
Blue boulder clay.....	73	73
Sand just above rock, water.....	10	83
Dundee (Corniferous):		
High grade limestone with some chert nodules.....	63	146
Quite heavy flow from 86 to 88 ft.; rank in hydrogen sulphide gas; small flow at 135 ft.		
Upper Monroe or Detroit River Series:		
Lucas:	170	316
Bluish to brownish gray porous dolomite much of it finely laminated, with streaks of asphaltum. Small amount of gypsum. Poor in fossils. Flow from 155 ft. to 168 ft.; flow continuing down to 181 ft. Sulphurous; temperature at 180 ft. was 49.5° F. (Cooper). Remarkably heavy flow at 191 ft. from a horizontal opening extending across the shaft. Water strong in sulphur and under a pressure of 90 lbs. per square inch, causing the shaft to fill in 3 to 4 hours.		
Amherstburg:		
Brownish, laminated dolomite.....	19	335
Anderdon:		
High grade limestone, rich in fossils. Some celestite.....	38	373
Flat Rock:		
Dark drab dolomite, with few casts and moulds of fossils. Some concretions and gypsum.....	47	420
Sylvania (Middle Monroe):		
Snow white sandstone more or less cross bedded. Generally incoherent compacted into sandstone from about 490 to 510 ft. Seepage flow of sulphur water throughout Sylvania sandstone, except for 27 foot stratum of dry siliceous dolomite (Sylvania dolomite). Mr. Bradt, the engineer, estimated the total flow above the base of the Sylvania as 2,000,000 gallons per minute, this being reduced to not over 500 gallons by the use of Portland cement forced into the fissures of the rock under a pressure of 1200 lbs. to the sq. in. This vein at the depth of 191 ft. required several carloads of cement before the flow could be controlled, and the services of a driver to insert the pipe at the proper point. Preparatory to blasting, holes were drilled obliquely about the margin of the shaft, one foot apart, and into these were forced all the cement slush that they would receive. In the case of the Sylvania, a concrete lining, 24 to 30 inches thick was required to restrain the flow. Below the Sylvania, the flow was greatly reduced and finally completely disappeared.	113	533
Lower Monroe, Bass Island Series:		
Raisin River:		
Bluish gray or brownish laminated dolomite with occasional oolitic strata. Line of separation between this and Sylvania very distinct. "Like a floor from which sand could be swept." Some chert nodules and pyrite. Bed of breccia encountered about 580 ft. Some fossils.....	124	657
Put-in-Bay (Possibly including Tymochtee):		
Bluish to brownish dolomite with seams of fossils. Thin strata of breccia and oolite. Some selenite, alabaster, anhydrite, calcite, asphaltum, and pyrite. Shaly and carbonaceous in places. Dolomite shows "gashed structure" at certain levels. Veins of salt encountered near bottom.....	220	877
Salina:		
Salt and dolomite irregularly mixed. No fossils found.....	83	960
Salt.....	10	970
Salt and dolomite.....	50	1020
Salt, slightly blotched with dolomitic slime.....	20	1040
Present bottom of shaft at 1060 ft.		
Salt and dolomite.....	70	1110
Salt.....	30	1140
Salt and dolomite.....	199	1339
Salt.....	25	1364
Dolomite.....	73	1437
Salt.....	369	1806
When entered, this bed will probably be found to be divided by minor strata of dolomite.		

Fort Wayne. Just below Fort Wayne, Detroit, the Edison Power and Light Company have put down a number of deep wells, of which a log of their No. 1 is given below.

EDISON POWER AND LIGHT CO., NO. 1 WELL.

Loc.: At plant just below Ft. Wayne. Record by A. C. Lane from samples.

Elevation 385 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Drift	97	97
S. 23-90 ft. Blue eff. calcareous clay, 10 in. casing to 102 ft.		
Dundee (Corniferous) limestone:		
Limestone	203?	300?
S. 160 moderate eff.; S. 185 fierce eff.; S. 300 fierce, chipping, bluish. A piece which may have broken from above is large and characteristic Corniferous with A. reticularis, Fenestella, etc. If there is not some mistake in the samples it seems quite probable that the 300 ft. sample happens to be from a coral reef in the Lucas. Eight inch casing to 330 ft.		
Upper Monroe or Detroit River Series:		
Lucas Dolomite	150	450
S. 400 brown, slow eff.; S. 440 same.		
Sylvania sandstone (Middle Monroe)	175	625
S. 430 pyritic sandstone, with some dolomite, secondary quartz addition; S. 500 clear white sand rock; S. 600 the same; compare Ford No. 4, 237-375, Wyandotte Eureka 230-360, Church 290-475; River Rouge 350-500; Solvay 410-490; Oakwood 418.		
Lower Monroe or Bass Island Series:		
Dolomite, brown	75	700
S. 625 cherty dolomite, with numerous white grains of solid chert as well as dolomite; S. 650 dolomite, granular, sandy looking, brown, a few grains of sand.		
Dolomite, blue	25	725
S. 700 mainly dolomite, slow eff., a few grains of selenite, bluish.		
Dolomite, brown	50	775
S. 725 slow eff., dark, chipping; S. 750 massive brown coarse chips.		
Dolomite, light	125	900
S. 775 slow eff.; S. 800 pure dolomite; S. 845 almost wholly dolomite, a little anhydrite under microscope; S. 875 mainly dolomite and anhydrite in a trace.		
Anhydrite mainly	50	950
S. 900 about half dolomite, half anhydrite; S. 925 almost all anhydrite, a little gypsum.		
Dolomite	50	1000
S. 1000 mainly anhydrite with flakes of selenite and dark dolomite.		
Salina:		
Salt	25	1035
S. 1010 brown salt; S. 1025 white salt.		
Limestone	5	1040
Salt	30	1070
S. 1040 brownish white salt.		
Limestone	22	1092
S. 1080 mainly dolomite, a little anhydrite.		
Salt	25	1117
S. 1115 white salt.		
Limestone	5	1122
S. 1112 dolomite mainly, a little anhydrite.		
Salt	38	1160
S. 1140 clear, coarse grained salt, beds from 1010-1160 compare with Wyandotte 730-870.		
Limestone	120	1280
Six inch casing to 1180 ft.		
This probably marks the interval between the first and second epochs; (Volume V, 1895, p. 28), compare.		
S. 1160 is dolomite salt, anhydrite and quartz.		
S. 1165 is half dolomite, half anhydrite.		
S. 1200 and 1200b are reddish brown, rusty with some sand, but mainly dolomite, no anhydrite.		
S. 1250 gave slow eff., is stuck together and has more dolomite, than anhydrite.		

EDISON POWER AND LIGHT CO., NO. 1 WELL.—Concluded.

Elevation 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Salt.....	12	1292
Compare Wyandotte 940-970.		
Limestone.		
S. 1300 is mainly dolomite with some anhydrite.		
Argillaceous limestone "Shale".....	55	1365
S. 1310 greenish, earthy, with a granular calcite powder.		
Limestone.....	80	1445
S. 1400 light buff, slow eff., with some anhydrite.		
Salt.....	191	1636
S. 1445 not clean, brown salt, at 1500 ft. and 1600 ft. clean salt.		
Compare Wyandotte 1080-1235.		
Limestone and anhydrite.....	20	1656
S. 1655 Strong reaction for SO ₂ , brilliant polarization colors. 1656 feet of 3-inch tubing.		

Windsor, Ontario. Across the Detroit river in Windsor the Canadian Pacific railroad drilled a number of wells. Their No. 11 well shows that the Sylvania is 590 feet below the surface and the first salt at 1167 feet. This indicates a rapid deepening north from Wyandotte.

CANADIAN PACIFIC R. R. WELL NO. 11, WINDSOR.

Elevation about 610 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface and hard white dolomite (Dundee absent?):	235	235
Monroe or Detroit River series:		
Dolomite, hard fawn colored.....	15	250
Dolomite, marly, drab.....	50	300
Limestone, dark color, petroliferous.....	25	325
Dolomite marly.....	10	335
Dolomite marly, drab.....	30	365
Dolomite marly, gray.....	25	390
Dolomite vesicular, drab.....	20	410
Limestone.....	30	440
Dolomite, crystalline, fawn colored.....	20	460
Limestone, drab.....	75	535
Sylvania (Middle Monroe):		
Sandstone, quartzose (Sylvania).....	55	590
Lower Monroe or Bass Island Series:		
Dolomite, fawn.....	10	600
Dolomite, with gypsum, gray.....	40	640
Dolomite, shaly, drab, somewhat arenaceous.....	30	670
Dolomite, drab gray.....	90	760
Dolomite, fawn (dolomite? 670-700).....	40	800
Dolomite, hard, drab gray.....	25	825
Dolomite, shaly, gray.....	15	840
Dolomite, fawn.....	40	880
Dolomite, drab gray.....	80	960
Dolomite, fawn gray.....	70	1030
Dolomite, drab gray with gypsum.....	40	1070
Dolomite, shaly, drab gray.....	30	1100
Dolomite, drab gray.....	27	1127
Salina:		
Salt.....	40	1167

Detroit. The Stroh Brewing Company's well, excepting the Wyandotte well, is the deepest boring along Detroit river and may have reached the Niagara. The record as given below is one obtained from verbal reports and is lacking in detail.

STROH'S BREWERY WELL.

Loc.: At plant on Gratiot Ave., Detroit.

Elevation about 620 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Blue clay	110	110
Hard pan	30	140
Boulders	14	154
Traverse Formation	164	300
Dundee limestone and Upper Monroe, or Detroit River dolomites, with sulphur water in the latter	315	615
Sylvania sandstone	85	700
Lower Monroe, or Bass Island Series:		
The lime rock hard at 730 ft., sandy at 80 ft., and hard pan 900 to 1150 feet.		
Salina:		
Salt	55	1205
Limestone	201	1406
Salt	250	1815
Limestone (Lower part Niagara?)	282	2097

North Detroit. The Detroit Natural Gas Co. drilled a well in North Detroit to the depth of 770 feet striking a small quantity of gas with water in the surface gravels and in the Antrim black shales just below the drift.

DETROIT NATURAL GAS CO. WELL.

Loc.: 7 mi. N. and 3 E(?) of Jefferson Ave.

Elevation about 630 ft.? A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Gravel and gas (would burn)	100	100
Gravel	25	125
Antrim:		
Black shale	8	133
Hard shale	7	140
Gas and water (would light) at 165 ft.		
Black slate	52	192
Traverse (Hamilton) Formation:		
Shelly sandstone	34	226
Limestone	14	240
Soapstone (calcareous shale)	160	400
Hard slates and limestone	75	475
Dundee (Corniferous):		
White sandstone, quite hard	105	580
(Probably cherty limestone shales).		
Limestone (Monroe)	190	770
Still in limestone.		

Eloise. An 850 foot well was drilled for gas by C. C. Nims at the Wayne County Infirmary at Eloise. The well (625 ft. A. T.) struck the Traverse formation at 130 feet and this yielded a flow of fresh water. A strong mineralized brine was struck in the Monroe Group with some indications of oil.

LOCAL STRUCTURES IN SOUTHEASTERN MICHIGAN.

The strike of the rock formations from the Ohio line through Monroe county is in general northeast, but in Wayne county it becomes almost due east, the strata apparently lapping around the end of the Cincinnati anticline in Essex and Kent counties, Ontario. The general dip of the Sylvania in Monroe county is therefore northwest, and from the quarries of the National Silica Company (Sec. 2, Raisinville Twp.) to Ann Arbor the average is over 38 feet per mile. In Wayne^a county, however, the average dip of the strata cannot be accurately determined owing to the lack of reliable data. Northward along Detroit river the dip of the Sylvania varies from 27 to 32 feet per mile, and westward from Detroit to Ann Arbor, a distance of 32.5 miles, the Dundee and Sylvania dip respectively 15.7 and 14.7 feet per mile. The Royal Oak and Pontiac wells are nearly in the proper position from Detroit to give the true dip of the formations, but unfortunately comparison cannot be made for the Dundee in either the Royal Oak or the Pontiac well, since the formation cannot be distinguished from the Monroe. If the Sylvania is taken as a basis for comparison, the dip north-northwest from Detroit into Oakland county is about 21 to 22 feet per mile, therefore the average dip of the rocks in Wayne county is probably not over 25 feet per mile in the same general direction.

Wyandotte Anticline. While the general dip of the rock strata in Monroe county is to the northwest at not over 40 feet per mile, and in Wayne county is north-northwest at perhaps less than 25 feet per mile, the local dips are not only discordant but much greater, indicating local warping and folding. At South Rockwood, the Sylvania is about 565 feet above sea level, but to the northeast in the Swan well, Grosse Isle, it is only 266 feet A. T. From the latter well northward to Trenton and beyond the Sylvania rises to 290 and 300 feet A. T. in the Church wells, to 350 feet A. T. at the Eureka Iron Works, and 388 feet A. T. in the Morton Salt Company wells, Wyandotte. Northeastward from the latter place, the Salina begins to deepen, being struck in the Ford wells at Ford City at 345 and 230 feet A. T., 180 feet and 142 feet A. T. in Ecorse, and 155 feet A. T. in the Oakwood salt shaft. At River Rouge, there is a rise to 210 feet A. T.,

^aW. H. Sherzer: *Geology of Wayne county*, Pub. 12, Geol. Surv. 9, 1911, pp. 206.

but to the north and northeast the descent is rapid, as at Fort Wayne the Sylvania occurs at 135 feet A. T., in Windsor 60 to 70 feet A. T., and at Stroh's Brewery on Gratiot avenue, Detroit, the Sylvania is 5 feet below sea level. The salt horizons show a similar rise from Trenton to Wyandotte, and then a sudden deepening to the northeast. (See references in record of Morton Salt Company well.)

From the foregoing facts, it appears that the crest of an anticline crosses Detroit river from Ontario and passes near Wyandotte. According to Sherzer,⁷ the axis of the anticline strikes south 60° west through a point about five miles north of the Woolmuth quarry (sec. 29, Exeter Twp.), Monroe county.

Stony Island Anticline. In deepening the Livingston channel at the Lime Kiln Crossing in Detroit river, a cofferdam was constructed exposing the river bed for more than a mile. In excavating the channel through the ledge of limestone, which crosses the river at this point, a cut 3500 feet long was made through limestone strata which dip steeply toward the southwest instead of northeast, as indicated by the drillings along Detroit river. In the northern portion of the exposed area near the head of Stony Island, a pronounced anticlinal fold⁸ extends across the river in an east-west direction. The dip on the south limb, according to Sherzer, is 1°58', or about 180 feet per mile in a direction S. 50° W. Eastward in the Anderdon quarry on the Canadian side of Detroit river the dip is much steeper, being over 300 feet per mile in a direction S. 23° W., and, in the Patrick quarry on the south end of Grosse Isle, the dip is S. 30° W., and ranges from 1½ to 2°, or about 140 to 185 feet to the mile. The extent of the area over which the steep southwesterly dips prevail indicate that the fold is of considerable magnitude, apparently much larger and more pronounced than the anticline near Wyandotte.

In the Sibley quarry, the rock strata have been disturbed as the strata dip in a direction 5° south of west instead of north-northwest, and at 200 to 230 feet per mile. In the Christiancy or Bullock quarry on the Macon river two miles northeast of Dundee, the dip is only about 25 feet per mile west-northwest, while at Dundee it is nearly 120 feet. Such striking irregularities in dip, and the presence of at least two anticlines, are indicative of favorable conditions for the occurrence of oil and gas, but so many holes have been drilled to the Salina horizon in Monroe and Wayne counties without striking any noteworthy amounts of either oil or gas, that the chances for finding these mineral products in large quantity in strata above the Niagara do not seem promising. A few miles east of Detroit river in Ontario, oil and gas have been found in great quantities in the Niagara and

⁷The Monroe Formation, Pub. 2, Geol. Ser. 1, Geol. and Biol. Surv., 1900, p. 57.

⁸W. H. Sherzer: Geology of Wayne county, Pub. 12, Geol. Ser. 9, p. 214.

the Medina especially. Possibly these formations, particularly in the vicinity of the Stony Island and Wyandotte anticlines, may likewise contain oil and gas in large amounts.

WASHTENAW COUNTY.

West and northwest of Detroit toward the center of the Michigan Basin wells have been drilled at Ann Arbor, Ypsilanti, Royal Oak and Pontiac.

Ypsilanti. A number of wells have been drilled at Ypsilanti for sulphuretted brines derived from the mixture of brines from the Berea grit, the Traverse and Dundee limestones. The oldest well is the Cornwell mineral well, 750 feet in depth, on the flats along Huron river. Only a poor record of this is available; and of the Moorman well, about 965 feet deep, there is only the record of the casing. Fresh water was struck in the latter between 125 and 150 feet, and the first flow of mineral water was struck at 400 feet, which was saltier than the lower one. Gas (H_2S) was struck at about 550 feet.

It is to be noted in the Atlantis and the Banner Oil Company wells that the Berea sandstone at the base of the Coldwater is not a definitely recognizable horizon, though at Ann Arbor in the Court House well Rominger correlated 92 feet of coarse gray brine bearing sandstone with this horizon.

ATLANTIS WELL.*

Loc.: North of State Normal College Campus, Ypsilanti. T. C. Owen, owner.

Elevation 785 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand, clay, gravel, etc., unconsolidated.....	185	185
Antrim:		
Shale, soft.....	4	189
Sandstone, fine, slightly calcareous, fresh water.....	10	199
Limestone, fine—all dissolves in acid.....	10	209
Shale, dun, dark; lower 74 ft. black.....	84	293
Shale, sandy, dun.....	64	357
Traverse:		
Sandstone, very fine, slightly calcareous; yields bromine water.....	4	361
Limestone, pale, cherty.....	10	371
Shale, sandy.....	5	376
Limestone, ranging from pale and cherty to dun and sparry. Brine at 404 ft. directly beneath a very hard streak.....	43	419
Shale, bluish to dun, in places gritty.....	22	441
Limestone, varying from silicious to pure.....	24	465
Shale.....	21	486
Dundee? (Top uncertain but probably below 525ft. Cf. Banner Oil and Gas Co. well.):		
Limestone, varying from pale to dun, with some shaly partings, portions magnesian, others silicious; contains sulphurous (H_2S) water.....	138	624
Unrecorded.....	184	808
Monroe probably below 680 ft.....		808

*Record from A. Winchell's *Mss.*, by W. H. Sherzer, *Geol. of Wayne County*, Pub. 12, *Geol. Ser.* 9, 1911, p. 189.

In 1904 the Banner Oil and Gas Company and the Ypsilanti Development Company drilled another well at Ypsilanti on the Cramer farm about 300 feet from the old Cornwell well and near the city water works.

BANNER OIL & GAS CO. WELL.

Loc.: Three hundred feet from Cornwell well near Ypsilanti Water Works plant. Banner Oil & Gas Co. and Ypsilanti Development Co. A. H. Marsh, contractor. Samples at 700, 1150 and 1200 ft.

Elevation 682 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene.	90	90
At base of gravel water flows with T. 50.2° T. 49.7° at 90 ft., 10 inch drive pipe to 91 ft., T. 51.2° at 128 ft.		
Devonian Antrim:		
"White shale"	51	141
"Some gas" at 135 ft.? A little water, no odor.		
Black shale	150	291
Traverse Formation:		
Limestone shale	25	316
With a flow of gas. Hard shells at 300 ft. T. 53° F.		
Brown shale	204	520
This Traverse is also reported as 50 ft. limestone, then blue shale, then black shale, then limestone, then black shale, and the change to Dundee at 525 ft. At 520 ft. T. 57.2° F.		
Dundee limestone:		
Limestone	160	680
S. at 600 tests limestone according to Sherzer. Mineral water at 525 ft., 530 ft. with gas H ₂ S, also at 570 ft.		
Upper Monroe:		
Dolomite	80	760
S. at 700 ft. slow eff. dolomite; at 680 ft., more water quite salty with some gas and traces of oil, e. g., at (730 ft.) or 720 ft., at which point it was fruitlessly shot with nitroglycerin, Nov. 16, 1904.		
At 710 ft. T. 59.4° F.	400	1200?
Sylvania:		
White sandstone "375 ft. to 390 ft." of it at 1150 ft.		
S. 1150 ft. typical Sylvania sandstone, white, Dec. 17, 1904.		
S. water at 1175 ft.		
S. 1200 brownish sandstone, Feb. 9, 1905, looks like the samples near the bottom of the Sylvania.		
Well 1210 ft. deep. Ypsilanti Press, Oct. 4, 1905. ("Has it been deepened?"—Lane.)		

Ann Arbor. There are two wells at Ann Arbor; one, known as the old Court House well, was reported by Winchell and Rominger and the other, the Campus well of the University, is given below. Samples were taken for the Survey by Prof. Russell and careful notes were made by Prof. H. D. Campbell of the University and Mr. Frueauff of the Ann Arbor Argus.

CAMPUS WELL.

(Drilled in 1899-1900.)

Loc.: Campus of University of Michigan, Ann Arbor. Record by Dr. A. C. Lane.

Elevation 875 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Soil, fine sand	45	45
Gravelly, 10 ft., large boulder at 80 ft., casing to 90 ft.	45	90
Bluish clay, large boulder at 113 ft.	145	235
Coldwater shales:		
Bluish shales	30	265
Red shale	15	280
Plugged at 287 ft. and water above analyzed 4.3 per cent salt.		
Blue shale	75	355
Fine soft gray and black shale	20	375
Fine gray sandy shale	10	385
Fine bluish shale	15	400
Berea grit:		
Fine gray sandstone	15	415
(No water noted).		
Fine sandy shale	25	440
Glossy black shale	5	445
Fine gray sandy shale	75	520
Salt water at 515 ft. and below.		
Antrim shales:		
Fine black and green shale	10	530
Fine gray sandy shale	15	545
Very fine black shale	15	560
Black bituminous shale	15	575
Coarse gray sandstone	5	580
Black sandy shale	20	600
Black bituminous shale	80	680
Traverse Formation:		
Shale with pyrite	5	685
Gray calcareous shale	60	745
Dundee limestone:		
Gray cherty limestone	30	770
Light gray limestone	30	800
Gray argillaceous limestone, some gas indications	130	930
Upper Monroe:		
Light gray dolomite	40	970
Limestone at 950 feet struck a mineral water charged with H ₂ S which rose 300 ft. and contained 13 per cent salts, according to Eberhard.		
Light gray dolomite, sandy	60	1030
Nov. 18th operations were suspended for a month at the end of the first 1000 ft. in an oily dolomite or limestone.		
Light gray dolomites with Sylvania sand grains	205	1235
Jan. 5th at 1065 ft. a red rock with much iron was struck.		
Sylvania sandstone:		
Pure white friable sandstone	35 +	1270 +
According to newspapers at 1275 ft. on Feb. 10th another mineral water strong of H ₂ S with 17 per cent salts (Eberhard) was struck in limerock.		
At 1300 ft. the rock is said to have been a little softer. The well was shut down Feb. 26, 1900, at 1326 ft., plugged at 283 ft. and tested. Then a cement plug of 25 ft. was put on top, but the analysis of the water remained practically the same.		

OAKLAND COUNTY.

Royal Oak. Two wells have been drilled at Royal Oak, one 1400 feet in depth and the other 2502 feet penetrated the Salina for more than 900 feet. The record of the deeper well is given below. Little or no signs of oil or gas were noted anywhere in the drilling, although there were numerous shale gas wells in the drift in south-eastern Oakland county.

ROYAL OAK WELL.

Mfg. & Gas Co., Hugh Monroe, driller.

Elevation 678 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or Surface:		
Clay.....	40	40
Gravel.....	5	45
Clay.....	25	70
Quicksand and gravel.....	94	164
Antrim (Huron):		
Black shale.....	141	305
Traverse (Hamilton):		
Limestone.....	85	390
Brown shale.....	130	520
Dundee (Upper Monroe or Detroit River Series in lower part):		
Salt water at 548 ft. and 583 ft.		
Limestone containing salt water. (As this record does not distinguish dolomite and limestone, we cannot fix the boundary between the Mon- roe and Dundee limestone).....	316	836
Salt water at 720 ft.		
Sylvania:		
White sand. Salt water at 836 ft.....	154	990
Very soft white sandstone 836-1105 ft.		
Limestone. "Struck white sand 990-1095, very soft," (May this be anhydrite?—Lane.).....	115	1105
Lower Monroe or Bass Island Series:		
Very gritty hard limestone.....	20	1125
Dark sandrock, gray.....	15	1140
Blue hard gritty limestone.....	35	1175
Very soft light colored lime.....	40	1215
A little closer.....	45	1260
Hard close bluish limerock.....	145	1405
Hard gray sandrock.....	5	1410
Hard limerock.....	10	1420
Hard gritty limerock.....	45	1465
Rotten lime or shale. (The "shale" and "slate" are probably largely anhydrite, or at times dolomitic marl).....	78	1543
Salina:		
Solid rock salt.....	97	1640
Hard shale.....	10	1650
Nice quality of salt.....	45	1695
Slate, rotten lime or shale, marly.....	40	1735
Salt.....	57	1792
Hard blue lime.....	18	1810
Shale.....	10	1820
Salt.....	80	1900
Soft gray lime.....	10	1910
Hard lime.....	95	2005
Salt.....	15	2020
Slate.....	95	2115
Salt.....	35	2150
Slate.....	15	2165
Salt.....	20	2185
Slate.....	15	2200
Salt.....	100	2300
Slate.....	15	2315
Salt.....	160	2475
Hard blue lime.....	27	2502

Mutual Oil & Gas Company's Well, Royal Oak. In 1913, a test well, for oil was projected by the Mutual Oil & Gas Company of Detroit. Fifty acres of land near Royal Oak were bought and capitalized at \$162,000. The land was divided into 5400 parcels 20 feet square, which were to be sold at \$30.00 each. A certain portion of the proceeds was to pay for the land, another the promoters for their work in organizing the company and selling the stock, and the third portion for the drilling. In such stock schemes, the charges for purchas-

ing the land and promoting the enterprise are so great that there is relatively little money available for actual drilling.

The test well was to be drilled on land which has one or more surface gas wells. The idea was, that by going deeper, larger quantities of gas would be struck. As the numerous "shale gas" wells in Oakland county are in the belt underlain by the black Sunbury shale, the Berea grit and the Antrim black shale, the gas in the drift is undoubtedly a leakage from these formations. Any well more than a few hundred feet deep will pass completely through these petroliferous formations. Royal Oak well is well down the northeast limb of the low broad anticline between Pontiac and Adrian with its crest near Ann Arbor, and therefore it is apparently in an unfavorable position. The above project was finally abandoned without doing any drilling.

Pontiac. The Pontiac Natural Gas & Oil Company, drilled a well 1505 feet deep at Pontiac, Oakland county. A little gas was found between 1305 and 1310 feet, and also in the limestone at 1497 feet. The Berea sandstone, although exceptionally thick and overlain and underlain by bituminous shales, apparently gave little sign of either oil or gas.

PONTIAC WELL.

Pontiac Natural Gas & Oil Co., G. S. Duncan, contractor. Record by C. E. Wright, from samples and driller's log.

Elevation 934 ft. A. T.	Thickness, feet.	Depth, feet.
Surface.....	320	320
Coldwater:		
Blue shale.....	10	330
Blue argillaceous shale.....	10	340
Calcareous argillaceous sandy shale; light blue; very fine grained.....	30	370
Sandy argillaceous shale, light blue.....	70	440
Sandy argillaceous shale.....	40	480
Reddish argillaceous shale.....	20	500
Sunbury shale:		
Dark brown argillaceous shale.....	35	535
Berea sandstone:		
Light drab sandstone; fine grained. Salt water.....	20	555
Light drab sandstone, fine grained.....	17	572
Gray sandstone.....	236	808
Antrim shale:		
Black shale.....	157	965
Traverse Formation:		
Coarse-grained argillaceous limestone, dark drab.....	35	990
Fine-grained limestone, light drab; 2 per cent insoluble residue.....	10	1000
Limestone, light drab and grayish white; 8 per cent insoluble residue.....	7	1007
Limestone, light gray; 20 per cent insoluble residue.....	8	1015
Sandy limestone, dark drab; 20 per cent insoluble residue.....	35	1050
Argillaceous limestone; 10 per cent insoluble clay residue.....	15	1065
Light blue calcareous clay; 90 per cent insoluble residue.....	50	1115
Salt water; very strong brine at 1115 ft.		
Dundee limestone (top above 1220 ft.) and Monroe Beds:		
Monroe not separated from Dundee.		
Limestone, light gray, drab to dark drab 1220 to 1350 ft.		
Show of gas at 1300 ft.		
Sandy limestone; light gray, brisk eff.; residue 20 per cent gray sand and some glassy grains at 1350.		
At 1497 ft. in gas-rock for 40 ft. (?), but 1100 ft. water in well.		

South Lyon. At South Lyon (sec. 30, T. 1 N., R. 7 E.), a well was drilled to 1350 or 1400 feet in depth, but only a meager record is available. Rock was struck at about 70 feet, mineral water above 800 feet, and limestone (Traverse and Dundee probably) from 1000 feet to the bottom. Above 1000 feet are sandstones and shales, the latter in places black.

HOLLY MUNICIPAL WELL.

Notes kept by D. M. White of well drilled at Holly, by Kinney and Coleman: 8 inch well.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand and gravel	140	140
Soft clay	40	180
Sand and gravel	10	190
Soft clay	40	230
Like we had at 140 to 180 feet.		
Sand and gravel	35	265
Bottom of pipe 265 feet.		
Lower Marshall:		
Light drab shale with shells of sandstone running through it	135	400
Coldwater:		
Light drab shale very much like clay, but does not cave, soft	130	530
Gray sand rock; a little bit of water with salty taste	7	537
Blue shale, some harder than light drab shale	73	610
Dark sand rock, more salty water	10	620
Light drab shale	50	670

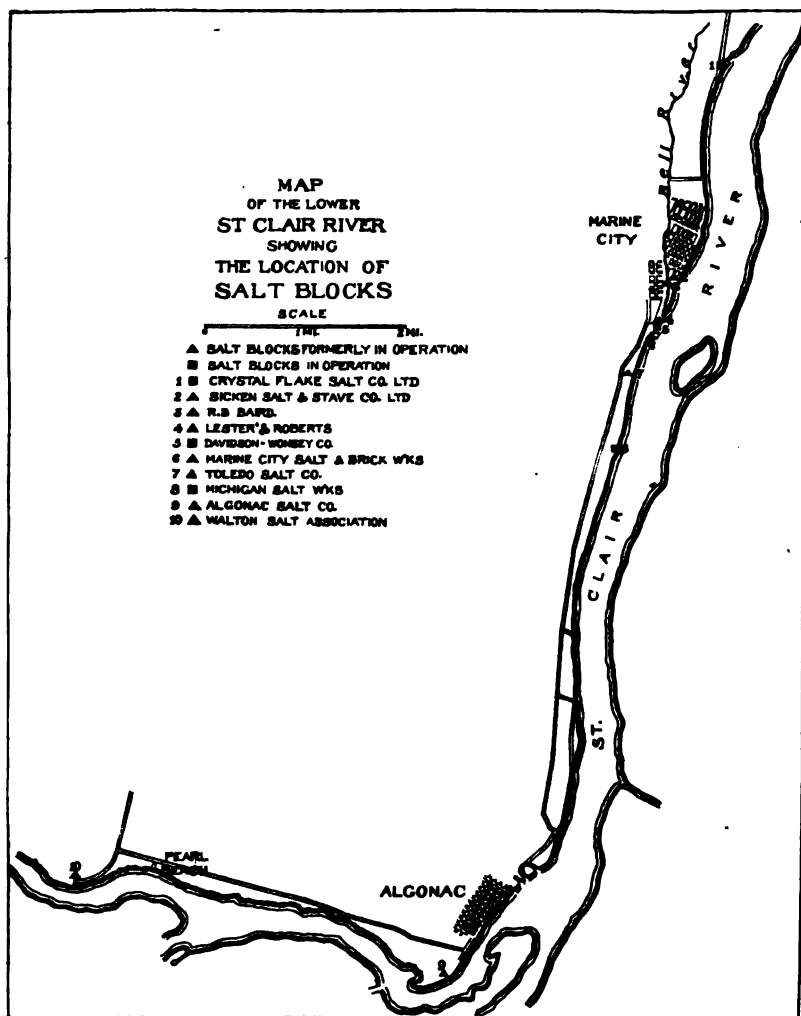


Figure 10. Map showing the location of salt blocks and salt wells along St. Clair river (after C. W. Cook).

MACOMB COUNTY.

Northeastward from Detroit to Port Huron numerous wells have been drilled for salt, oil, or mineral water. (Fig. 10.) Many wells have been drilled at Mt. Clemens for Mineral water and at Marine city and St. Clair for salt. The records of these and other wells indicate not only that the strike of the formations becomes easterly, but that there is a great discordance in the dip of the strata in Macomb and southern St. Clair counties.

Mt. Clemens. The record of the Mt. Clemens No. 3 well shows that the base of the Dundee horizon drops from 145 feet in the Oakwood salt shaft to 400 feet below the surface and the Sylvania from 410 to 965 feet. The dip of the latter is, therefore, about 21 feet per mile and of the former only about 8 or 9 feet.

MT. CLEMENS WELL NO. 3.

Loc.: Claim No. 141. Owner, Mr. Coursin; driller, Mr. Nims. Drilled in 1892. Samples furnished by driller, through T. M. Crocker.

Elevation 617 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Wet dark gray sand with an oily smell and moderately free eff.	35	35
Rock at 123 ft.?		
Record missing.	88	123
Antrim shale:		
Burns with an aromatic odor, in shaly flakes; black; smells oily.	17	140
Like the above, not so bituminous, tastes of ferrous sulphate.	70	210
Traverse (Hamilton) Formation:		
Mixture of black shale and of a limestone like that at 260 ft.; eff. not very brisk; traces of gypsum in solution.	8	218
Light buff limestone with traces of shells; very brisk eff.	67	285
The same; no gypsum.	15	300
Unrecorded.	100	400
Dundee (Corniferous) limestone:		
Light buff even grained; very brisk eff.; no CaSO_4	160	560
Light buff; even grained; very brisk eff.; no CaSO_4	23	583
Gas at 600 ft. and at intervals for the next 200 ft.		
Upper Monroe:		
As at 560.	17	610
As at 560, but slower eff.	10	620
Like 560 in color, but with many large pieces of gypsum, and slow eff.	30	650
The same, with a certain amount of gypsum.	50	700
Brown; slow eff., except a few grains; some gypsum.	20	720
Dark buff; slow eff., gypsum.	40	760
Dark gray, slow eff., gypsum.	25	785
Dark gray; gypsum; eff. faster at 890 ft. than at 900 ft., quartz occasional.	105	890
Dark brown; with a trace of gypsum.	10	900
Like No. 720 in color; moderate eff.; occasional quartz; trace of gypsum.	20	920
Brownish buff; quick eff.; a little quartz, chert and clay.	20	940
Like 940, but a shade lighter.	25	965
Sylvania sandstone:		
Granular white sandstone, very pure; rounded grains averaging 0.3 mm. in size, and smaller angular grains, averaging 0.15 mm. in diameter, like the sand at 1920 ft. and 1950 ft. at Kalamazoo.	35	1000
Unrecorded.	60	1060

New Baltimore. The Dundee drops from 400 feet at Mt. Clemens to 690 feet below the surface at New Baltimore. This indicates a dip of about 32 feet per mile to the northeast, or three times as great as that from the Oakwood salt shaft to Mt. Clemens, and probably greater than the average north-northwest dip in Wayne county, although accurate calculations cannot be made for the latter on account of the lack of reliable data.

NEW BALTIMORE WELL.

C. M. Swift, owner. Drillers, J. J. Mason & Co.

Elevation about 588 (?) ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface.....	120	120
Antrim shale:		
Blue shale.....	5	125
Black shale.....	335	460
Compare St. Clair, 400; Marine City, 460; Pontiac, 965; Mt. Clemens, 218.		
Traverse Formation:		
Limestone and calcareous shales.....	20	480
Limestone.....	50	530
Compare St. Clair, 630; Pontiac, 1065.		
Blue shale.....	160	690
Compare St. Clair, 790; Algonac, 513; Marine City, 740 to 635; Pontiac, 1235; Mt. Clemens, 400.		
Dundee (Corniferous) limestone:		
Limestone high grade.....	130	820
Compare St. Clair, 910; Marine City, 825 to 770; Mt. Clemens, 610.		
Monroe Group, including Salina:		
Dolomites.....	290	1110
Gypsum bed (anhydrite) 860 to 870 ft.		
Compare St. Clair, 990.		
Gypsum bed 885 to 895 ft.		
Brown dolomite, 920 to 940 ft.		
Compare Marine City, 1060 ft.		
Limestones.....	165	1275
Compare St. Clair, 1380; Marine City, 1220.		
Brown dolomite and gypsum.....	85	1360
Blue dolomite, shale and gypsum.....	35	1395
Compare St. Clair, 1480; Marine City, 1390.		
Buff dolomite.....	50	1445
Blue and brown dolomite and gypsum.....	155	1600
Compare St. Clair, 1600; Marine City, 1604.		
Salt.....	40	1640

Romeo. At Romeo, a well 1575 feet in depth was drilled by M. Porter for the village in a vain search for potable water. The brine, or mineral water struck in the lower part of the well rose about 1000 feet. The record, as furnished by Fred E. Hipp, cannot be satisfactorily correlated. A sandstone from 180 to 240 feet apparently corresponds to the Richmondville, but it may be the Berea since in a well drilled by O. N. Phillips on the D. M. Ferry & Company farm, sec. 23, Avon township, Oakland county, a brine bearing sandstone overlain by 45 feet of black shale was struck at 230 feet. The driller, upon being shown samples of Berea sandstone and Sunbury shale from the Saginaw wells, pronounced them identical in character with the rocks encountered in the Ferry well, and in many other wells drilled by him in Oakland and northwest Wayne county. The sandstone and shale correspond to the Berea and Sunbury respectively, yet it cannot be asserted that the upper sandstone at Romeo corresponds to the Berea horizon, as stray sandstones resembling the Berea are known to occur in the lower part of the Coldwater shales. The correlations as given in the record below are merely tentative.

ROMEO WELL.

Loc.: Near water works? Mat Porter, contractor. Record from F. E. Hipp.

Elevation about 75 feet above R. R. station.	Thick- ness, feet.	Depth, feet.
Pleistocene or drift:		
Sand and gravel.....	150	
Coldwater shales (probably Antrim and Traverse in lower part):		
Very light rock, floats.....	30	180
Freestone, i. e., sandstone (Richmondville?).....	80	240
"Soapstone," black shale and slate.....	510	750
Bed of rock salt (?) and well caves badly at 750, Berea horizon?		
"Soapstone," black shale and slate.....	300	1050
Dundee? (Corniferous) limestone:		
Sandstone or grindstone rock, like the Huron county rock, only it has harder streaks in it. (This may very likely be the cherty Corniferous limestone.—Lane).....	250	1300
Monroe?		
Limestone, light gray.....	70	1370
Soft rock; rotten limestone; caves badly.		
Plaster beds at 1370 ft.		
End of 4½ in. hole at 1420 ft.		
Gas veins and rock badly caving at 1440 ft.		
End of drill in soft rock at 1575 ft.		

ST. CLAIR COUNTY.

Algonac. Just south of Algonac on St. Clair river, a well 1727 feet in depth penetrates the salt beds of the Salina. This well is either so far east that it is beyond the limits of the Antrim black shale, or the well is over a rock valley where the black shale is cut out by erosion. The Sylvania is not present as a sandstone; apparently it is represented by a sandy dolomite.

New Baltimore is about 10 miles north of west from Algonac and the Dundee drops about 175 feet, or about 17 feet per mile from Algonac to the former place. This is much less than the northeasterly dip from Mt. Clemens to New Baltimore, although the maximum dip should be in general northwesterly toward the central basin.

ALGONAC WELL.

Loc.: South of Algonac on St. Clair river. Albert Miller, owner. Drilled in 1886. Driller's record. (Apparently this is one of the Algonac Salt Co.'s wells. See map.)

Elevation about 584 ft.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface, clay, etc.	208	208
Traverse or Hamilton:		
Soft white shale	85	293
Soft brown lime	20	313
Soapstone, soft, gray and sticky	200	513
Dundee and Monroe, not separated:		
Hard, mixed gray and brown limestone. (The records of this well do not show the distinction between limestone and dolomite)	767	1280
Yellow gypsum (probably anhydrite), 1180-1185 ft.	20	1300
Hard, mixed gray and brown limestone	75	1375
Blue shale; medium hard		
Salina:		
Gray, brown and white hard limestone	125	1500
Rock salt		
Shale and salt mixed; soft and hard	80	1580
Hard brown and white lime	25	1605
Rock salt	18	1623
Hard gray lime	10	1633
Salt	94	1727
Hard limestone at 1727 ft.		

Marine City. There are a large number of wells at Marine City which penetrate the salt beds. The records of seven of these wells are given in Volume V, but the Lester and Roberts, the National Salt Company, and the Morley are given below as representative of the others. The record of one of the Michigan Salt Co. wells, located south of the city, is also given. Some oil was struck in the National Salt Company's well in the top of the Salina.

LESTER AND ROBERTS WELL.

Record from samples preserved by J. R. Burr. Driller, Mathew Porter. Record by C. E. Wright.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface	50	50
Clay	150	200
Antrim:		
Hard pan, contains fragments of slate	20	220
Hard pan	10	230
Black bituminous slate, contains FeS ₂	70	300
Dark and light drab slate	20	320
Black bituminous slate, contains small pieces of coal	20	340
Dark drab bituminous shale, contains small pieces of coal and FeS ₂	10	350
Drab bituminous shale, somewhat calcareous	10	360
Traverse (Hamilton) Formation:		
Argillaceous dolomitic limestone	50	410
Al ₂ O ₃ 14.29. SiO ₂ 28.67.		
Light bluish gray to drab colored limestone	40	450
Light gray limestone	20	470
Light gray limestone, contains a little talc and slate	20	490
Light and dark gray limestone: small silicious residue	10	500
Soft argillaceous limestone (soapstone)	50	550
Al ₂ O ₃ 9.70. SiO ₂ 21.		

LESTER AND ROBERTS WELL.—Concluded.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Dark drab limestone.....	10	560
Calcareous argillaceous rock, gritless.....	75	635
Al ₂ O ₃ , 17.18. SiO ₂ , 41.30.		
Dundee (Corniferous) limestone:		
Light yellowish gray limestone.....	95	730
Light gray limestone, contains oblong concretions or possibly fossils, 5 mm.....	40	770
Upper Monroe or Detroit River Series:		
Dolomite, contains yellow specks.....	30	800
Light brownish drab dolomite; contains in residue a little anhydrite in white specks.....	30	830
Light gray dolomite; contains in residue a little anhydrite in white specks.....	25	855
Dolomite, light drab, contains in residue a little anhydrite in white specks.....	25	880
Hard dolomitic limestone, light gray, massive.....	25	905
Dolomitic limestone, contains a little anhydrite; also a few fragments of slate.....	30	935
Dolomitic limestone, contains a few fragments of slate.....	30	965
Dolomitic limestone, light drab, contains in residue a little anhydrite in specks.....	15	980
Dolomitic limestone, drab; even texture.....	10	990
Dolomitic limestone, dark drab.....	70	1060
Sylvania or Middle Monroe:		
Arenaceous limestone, dissolves bristly but leaves a large cherty sandy residue. Not organic.....	40	1100
Arenaceous limestone.....	30	1130
Lower Monroe or Bass Island Series:		
Limestone, light drab.....	30	1160
Limestone, light gray, contains a little gypsum.....	30	1190
Limestone, light gray, contains a little gypsum.....	30	1220
Dolomitic limestone, dark drab.....	5	1225
Dolomitic limestone, hard, light gray, yellow specks; large silicious resi- due.....	20	1245
Dolomitic limestone, very dark drab; large silicious residue.....	35	1270
Dolomitic limestone, light drab; small silicious residue.....	23	1293
Gypsum, drab and white.....	11	1304
Calcareous gypsum, dark drab; large residue, possibly argillaceous.....	26	1330
Calcareous gypsum, dark drab; very large residue, possibly argillaceous.. Si O ₂ =12.68.	35	1365
Calcareous gypsum, dark drab; large residue, possibly argillaceous; contains anhydrite.....	25	1390
Dolomitic limestone, light and dark drab; large residue slate, anhydrite, gypsum and silica and some organic matter.....	15	1405
Dolomitic limestone, light drab; large residue slate, anhydrite, gypsum and silica and some organic matter.....	20	1425
Dolomitic limestone, light and dark drab; large residue slate, anhydrite, gypsum.....	20	1445
Dolomitic limestone; light drab, residue slate, anhydrite, silica and some organic matter.....	20	1465
Dolomitic limestone, light drab; large residue of gypsum.....	20	1485
Gypsaceous limestone, light drab; large residue of gypsum.....	20	1505
Gypsaceous limestone, light drab; large residue of gypsum.....	33	1538
Calcareous clay, Al ₂ O ₃ , 22.12.....	41	1579
Anhydrite, SO ₃ , 59.42.....	20	1599
Gypsum, (anhydrite) white and dark drab.....	5	1604
Salina:		
Rock salt.....	33	1637
Gypsaceous limestone. SO ₃ =14.10.....	4	1641
(The gypsum is anhydrite.—Lane.)		

NATIONAL SALT COMPANY WELL.

Loc.: Marine City. Drilled in 1886. Record by C. E. Wright from driller's notes and samples.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Earth.....	150	150
Gravel.....	50	200
Antrim shale:		
Dark brown and black shale.....	200	400
Traverse (Hamilton) formation:		
Light gray limestone, with small amount of sand and gypsum, or anhydrite.....	75	475
Calcareous clay shale.....	95	570
Hard light drab shale.....	15	585
Calcareous clay shale.....	40	625
Dundee (Corniferous):		
Gypsum, argillaceous limestone.....	40	665
At 665 ft. struck some calcareous tufa that floated to the surface and when dry was fluffy.		
Light gray gypseous limestone, resembles sand.....	35	700
Hard grayish white limestone.....	25	725
Brown and white limestone mixed with small amount of gypsum and sand.....	25	750
Brine at 750 ft.		
Upper Monroe, or Detroit River Series:		
Brownish gray dolomitic marl with small residue of silica.....	60	810
Dolomitic drab limestone.....	10	820
Grayish white calcareous anhydrite.....	30	850
Drab dolomitic gypsum marl.....	10	860
Dolomitic gypseous marl.....	10	870
Dolomitic limestone.....	10	880
Light gray and drab dolomitic limestone.....	90	970
Dolomitic limestone, yellowish to buff.....	30	1000
Sylvania:		
Dark ochreous, sandy limestone, large residue of silica and flint.....	130	1130
Lower Monroe, or Bass Island Series:		
Buff dolomitic limestone.....	60	1190
Light gray dolomitic limestone, with residue of gypsum, anhydrite and silica.....	30	1220
Bluish gray dolomitic limestone with small residue of gypsum and angular grains of black flint.....	40	1270
Bluish gray dolomitic limestone, with large residue of gypsum, anhydrite and flint.....	60	1330
Buff sandy dolomitic limestone, with large residue of silica, anhydrite and gypsum.....	20	1350
Light bluish gray calcareous gypsum, large residue of gypsum and anhydrite.....	50	1400
Gray mottled with yellow dolomitic limestone.....	30	1430
Bluish gray dolomitic limestone, large residue of light and dark gypsum and anhydrite.....	20	1450
Gray dolomitic limestone, with small residue of gypsum, anhydrite and silica.....	60	1510
Dark drab gypseous limestone, large residue of clayey gypsum.....	10	1520
Grayish calcareous clay, with large muddy residue.....	30	1550
Dark drab dolomitic limestone, small residue of gypsum.....	10	1560
Dark drab dolomitic limestone, large residue of gypsum.....	10	1570
Salina:		
Rock salt. Oil and salt at 1577 ft.....	20	1590
Dolomitic limestone, small residue of gypsum and anhydrite.....	10	1600
Rock salt.....	30	1630

W. B. MORLEY WELL.

Loc.: One mile north of Marine City. Drilled in 1886. Record from samples.

Elevation about 600 ft.	Thick- ness, feet.	Depth, feet.
Pleistocene, or drift:		
Clay	150	150
Gravel	5	155
Clay	30	185
Hardpan (clay or shale)	45	230
Antrim shale:		
Brown shale	70	300
Black shale	160	460
Brown calcareous shale	5	465
Traverse (Hamilton) Formation:		
Hard silicious gray limestone	45	510
Light gray calcareous clay shale, large clayey residue	145	655
Light gray calcareous clay	95	740
Dundee (Corniferous) limestone:		
Light gray limestone, small silicious residue	50	790
Hard light gray limestone, small silicious residue	15	805
Gas and mineral water at 805 feet		
Hard light gray limestone, small silicious residue	10	815
Soft light gray argillaceous limestone	10	825
Upper Monroe, or Detroit River Series:		
Buff gypseous limestone, large residue of gypsum and anhydrite	55	880
Soft light gray limestone, small residue	20	900
Soft light gray limestone, small residue of anhydrite	30	930
Hard gray dolomite, small residue of black cherty quartz	65	995
Hard dark gray dolomite, small residue	15	1010
Grayish drab dolomite, medium residue of anhydrite and black grains of shale	55	1065
Sylvania (Middle Monroe):		
Dark buff sandy limestone, large residue of sand, 37 per cent of SiO_2	25	1090
Dark buff calcareous sandstone, 69.34 per cent SiO_2 , milk white and glassy	35	1125
Dark buff sandy limestone, 16.4 per cent SiO_2	55	1180
Dark buff sandy limestone, 43.5 per cent SiO_2	27	1207
Lower Monroe, or Bass Island Series:		
Chocolate buff dolomite, medium residue of silica	93	1300
Soft grayish drab dolomite, medium residue of silica	10	1310
Dark drab to yellow gypseous dolomite, large residue of silica, gypsum and anhydrite	30	1340
Light gray and yellow gypseous dolomite, large residue of gypsum and anhydrite	20	1360
Gray calcareous gypsum, large residue of gypsum and some clay	100	1460
Gray dolomite, small residue of silica and gypsum	10	1470

MICHIGAN SALT WORKS WELL NO. 2.

Loc.: At plant south of Marine City. Drilled in 1898. Log furnished by Mr. S. R. McLouth.

	Thick- ness, feet.	Depth, feet.
Pleistocene drift:		
Clay.....	150	150
Hardpan.....	15	165
Clay and gravel.....	35	200
Antrim shale:		
Black slate.....	200	400
Traverse (Hamilton) Formation:		
Lime.....	15	415
Soapstone. Hard to mill. Could cut about 4 ft. per hour with 4 inch stem 43 feet long.....	50	465
Darker and harder.....	110	575
Lime. (Dundee?) Average 2 ft. per hour with 5½ inch stem, 38 ft. long. Struck sulphur water at 710 and salt water at 725 ft.....	155	730
Brownish limestone. Soft. Easy on bits.....	50	780
Dundee and Upper Monroe:		
(?).....	15	795
Streaks of gypsum.....	5	800
Hard streak of lime.....	25	825
Gypsum.....	5	830
Hard.....	20	850
Gypsum.....	10	860
(?).....	10	870
Hard streak of lime.....	5	875
Soft blue gypsum.....	25	900
Limestone shelly.....	70	970
Averaged 15 inches per hour.....	30	1000
Flint limestone. Good drilling. 18 ft. in 12 hours.....	40	1040
Same.....	60	1100
Sylvania:		
Sandy limestone. Very hard.....	60	1160
Lower Monroe:		
Hard; 8 in per hour from 1160 to 1225 ft.....	140	1300
Caving rock and gypsum.....	70	1370
No trace of gypsum from 1370 to 1400 ft.....	30	1400
Very hard.....	100	1500
Same.....	70	1570
Salina:		
Salt, first bed.....	25	1595
Lime and (?) salt. (The record at this point is not clear, reading "10 ft. lime and 10 ft. of salt to 1605. Lime to 1612 ft.; lime 11 ft.").....	10	1605
Lime.....	7	1612
Lime.....	11	1623
Salt; top of lower bed at 1623 ft.....	128	1751
Lime at 1751 ft.		

St. Clair. The Diamond Crystal Salt Company have drilled a number of wells to the salt beds and preserved good sets of samples. In one of their first wells, the Dundee was struck at 790 feet, and this indicates a decided dip amounting to about 25 feet per mile north from Marine City. To the north of St. Clair, however, there is a rise again, since at Marysville, the Dundee is struck at 582 feet and at Port Huron 542 feet.

The record of other wells given in Vol. V showed very similar depths for the Dundee and the drop of the Dundee is so great from Marine City on the south and from Port Huron on the north that doubt was thrown on the correlations. The careful record of the Diamond Crystal Salt Co. well apparently substantiates the correctness of the older correlations. Across the river, however, in Court-right, the Dundee is apparently struck at 542 feet, or nearly 250 feet

higher. This rise is so abrupt as to indicate a fault along the river or a pronounced fold to the east in Ontario; otherwise the correlations in the record of the Courtright well must be greatly in error. Present evidence indicates that the correlations in the latter record are incorrect.

DIAMOND CRYSTAL SALT CO. WELL.

Loc.: Near plant. St. Clair. One of the older wells, drilled prior to 1901. Record from samples by A. C. Lane.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface.....	172	172
Antrim shale:		
Blue shale (Erie).....	110	310
Black shale (Huron).....	220	530
Compare Marysville, 298 ft., Marine City, 360 ft., Oakland, 840 ft., and New Baltimore, 400-460 ft.		
Traverse (Hamilton) Formation:		
Blue argillaceous limestones and dolomites, etc.....	100	630
Blue shale.....	160	790
Compare Marysville, 588 ft., Marine City, 630 ft., Oakland, 800 ft., Mich. Salt Co. No. 2, 575 ft. and New Baltimore, 695 ft.		
Dundee (Corniferous) limestone:		
Limestone.....	120	910
Compare New Baltimore, 820 ft.		
Monroe Formation:		
Dolomites.....	80	990
Compare Marine City, 800 ft.		
Gypsum and dolomite.....	40	1030
Compare Marysville, 345 ft., New Baltimore, 860-920 ft.		
Dolomite probably sandy about 1270 ft.....	1270	
Offset through Sylvania sandstone.....	240	1370
Compare New Baltimore, 1370 ft.		
Dolomite.....	80	1450
Anhydrite largely.....	50	1500
Dolomite.....	40	1540
Dolomite.....	70	1610
New Baltimore, 1600 ft., Marine City, 1577-1633 ft., and No. 3, 1668 feet.		
Salina:		
Salt and cavity.....	30	1640
Lime.....	10	1650
Dolomite and anhydrite.....	97	1747
Salt.....	50	1797
Lime (?).....	10	1807

DIAMOND CRYSTAL SALT CO. WELLS NOS. 6 AND 7.

Loc.: St. Clair. Composite record¹⁰ of wells Nos. 6 and 7 from driller's log. Started, Feb. 10, 1909. Record furnished by Mr. F. W. Moore.

	Thick- ness, feet.	Depth, feet.
Pleistocene drift:		
Clay.....	115	115
Hardpan and gravel.....	38	153
Antrim shale:		
Blue shale or slate.....	52	305
Brown shale.....	195	500
Traverse (Hamilton) Formation:		
Lime.....	12	512
Blue shale.....	10	522
Lime.....	20	542
Blue shale.....	23	565
Lime.....	25	590
Soapstone.....	110	700
Lime.....	10	710
Soapstone.....	50	760
Dundee (Corniferous) and Upper Monroe:		
Lime.....	60	820
Sharp hard lime.....	10	830
Lime. In part Dundee.....	290	1120
Hard brown lime.....	8	1128
Lime.....	32	1160
Sylvania:		
Hard sandy lime.....	20	1180
Very hard lime.....	20	1200
Very sharp lime.....	145	1345
Lower Monroe:		
Lime.....	55	1400
Very hard lime.....	85	1485
Mud vein.....	5	1490
Red shale.....	5	1495
Lime.....	75	1570
Hard brown lime.....	30	1600
Hard gray lime.....	20	1620
Salina (First salt at 1630 in No. 5, 1620 in No. 6, and 1623 in No. 7):		
Salt.....	33	1653
Lime.....	22	1675
Hard brown lime.....	10	1685
Lime.....	20	1705
Very hard lime.....	38	1743
Salt.....	20	1763
Lime.....	5	1768
Salt.....	10	1778
Shale.....	76	1854
Salt.....	30	1884
Lime.....	8	1892
Salt.....	10	1902
Lime.....	10	1912
Salt.....	8	2020
Lime.....	5	2025
Salt.....	105	2130
Lime.....	5	2135
Salt.....	30	2165
Brown lime.....	35	2200

¹⁰The record of the No. 7 well was not saved until after the first salt bed was reached at 1623 ft., compared with 1620 in No. 6. From the top of the first salt, the record of the No. 7 well is used since it passed through the last salt bed whereas the No. 6 well did not.

ONTARIO.

Wallaceburg. Wallaceburg, Ontario, is about 8 miles south of east from Algonac. At the former place the Dundee was struck at 750 feet, much lower than at Algonac (513 feet) and the dip southeast to Wallaceburg from Algonac appears to be nearly 30 feet per mile.

WALLACEBURG WELL.

Elevation about 585 (?) ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sands and clays	35	35
Boulder clay	85	120
Shale	180	300
Limestones	75	375
Shale and sandstone	74	449
Compare Marine City, 370-480 ft.		
Traverse (Hamilton) Formation:		
Limestone, "top limestone"	106	555
Compare Marine City, 600 ft.		
Shale, "top soapstone"	95	650
Compare Marine City, 640 ft.		
Limestone, "middle limestone"	15	665
Compare Marine City, 730 ft.		
Shale, limestone and clay	85	750
Dundee (Corniferous) limestone (Top of Monroe not separated):		
Light colored limestone	250	1000
Doubtless the lower part is dolomite and belongs to the Upper Monroe.		
Sylvania (Middle Monroe):		
Sandstone	100	1100
Lower Monroe:		
Fine grained dolomites	280	1380
Gypsiferous dolomites	320	1700
(No salt reported, the record may be imperfect.)		
Niagara (Guelph and Lockport):		
Dolomites	120	1820
Limestone	105	1925
Oil at 1865 ft.		
Calcareous and arenaceous shales	110	2035
Medina:		
Gray sandstone, red shale and marls	65	2100

LOCAL STRUCTURE IN MACOMB AND SOUTHERN ST. CLAIR COUNTY.

In the Pontiac well, the top of the Dundee cannot be determined, but using the base of the Antrim as a basis of comparison, the dip from Mt. Clemens to Pontiac is about 20 feet per mile to the west. Northeastward to New Baltimore the dip for the Dundee is over 32 feet to the mile, eastward to Algonac, 8 feet, and south of east to Wallaceburg, Ontario, about 15 feet. These discordant dips indicate the presence of an anticline of considerable extent in the vicinity of Mt. Clemens, but the available data does not indicate the precise position. Its axis apparently pitches in a general northwesterly direction.

At Algonac, the top of the Dundee occurs at 71 feet above sea level, and, using this horizon as a basis of comparison, the dip northwest to New Baltimore is over 17 feet per mile, north to Marine City and St. Clair, 15 and 18 feet respectively, northeast to Fort Lambton,

Ontario, apparently 66 feet, and southeast to Wallaceburg, Ontario, about 30 feet per mile. According to this, another anticline exists near Algonac, but the great discordance in the several dips makes its position and course very uncertain. A further study of the records of wells in Macomb and St. Clair counties and in Ontario tends to show that there are perhaps a series of anticlines and synclines in the region under discussion. A large syncline appears to extend northwest from Chatham, Ontario, through Wallaceburg toward Fort Lambton; a low anticline or terrace at Marine City, and a syncline at St. Clair. Future drilling may show that faulting plays an important part in causing the sudden and discordant dips in Macomb and southern St. Clair counties.

Conclusions. In conclusion, it may be said that the records indicate that there is marked warping and folding, or perhaps faulting, in the rock strata in Macomb and southern St. Clair counties, and that there are pronounced anticlinal structures in the vicinity of Mt. Clemens and Algonac. The drill holes, however, are so located that while they show the presence of anticlines and synclines they do not clearly indicate their position or direction. Such disturbances in general form favorable conditions for the occurrence of oil and gas, and it is not improbable that future drilling, especially to the Niagara and Medina, may show that some of these structures contain oil and gas in commercial amounts as they do a few miles east in Ontario.

CHAPTER V.

THE SAGINAW OIL FIELD.

THE SAGINAW VALLEY DEVELOPMENT COMPANY.

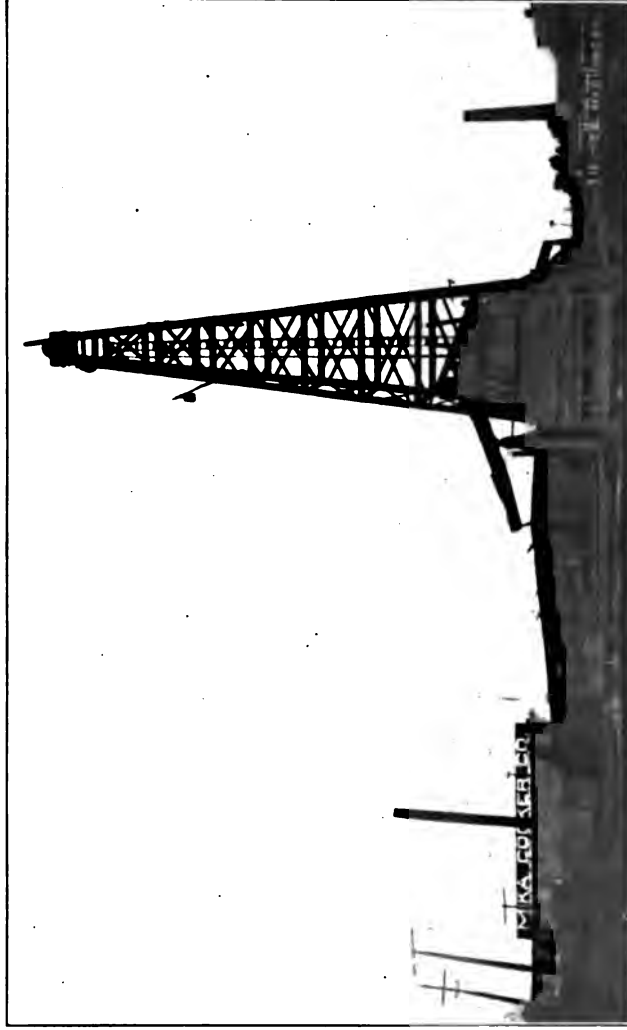
Some years ago Dr. A. C. Lane, then State Geologist of Michigan, wrote an article upon the oil and gas prospects in Saginaw Valley. This article appeared in the Michigan Miner of Saginaw and created considerable interest at the time, especially at Saginaw. Nothing came of it, however, and the article was forgotten until a reprint fell into the hands of some enterprising Saginaw business men in the winter of 1912. They became very much interested in the oil and gas possibilities of Saginaw Valley, as portrayed by Dr. Lane, and soon interested other business men of Saginaw. The Saginaw Valley Development Company was soon organized for the purpose of drilling three test wells, two to the Berea grit, and a third to a depth of 3500 feet or more, unless oil or gas should be struck in commercial quantity before that depth was reached. The officers of the company were Wallis Craig Smith, president; Clark L. Ring, vice-president; and N. N. Rupp, secretary and treasurer. At their request, the officials of the company were given a compilation and interpretation of the data by the Geological Survey which, though meager and inconclusive, was deemed sufficiently favorable to warrant a test of the Saginaw territory.

THE SAGINAW ANTICLINE.

Most of the evidence indicating favorable structural conditions for the occurrence of oil and gas in the region was derived from the numerous and comparatively shallow salt (fig. 11) wells along Saginaw river, drawing brine from the Upper Marshall sandstone.

Further evidence was afforded by drill holes at Midland, Caseville, Blackmar, Flint, Owosso, and St. Charles. The two deep wells at Bay City were of great value in giving a general idea of the probable thickness and character of the formations below the Marshall brine horizons.

The center of the Michigan Basin appears to lie in Midland and Isabella counties. Saginaw and Bay City are east of the center, therefore the strata in the vicinity of these places have a general westerly



THE GAREY-CASAMER NO. 1 WELL, SAGINAW.

dip which, on the average, is about 20 feet per mile. Since Saginaw is somewhat nearer the central basin corresponding strata at Saginaw should be deeper than at Bay City.

Upon platting the records of the salt wells along Saginaw river the Napoleon, or Upper Marshall sandstone, instead of being deeper at Saginaw is apparently 200 to 300 feet higher than at Bay City. This sandstone rises gradually from a depth of about 1900 feet in Bay City to about 610 feet in the old Wylie well near Bristol street bridge in Saginaw, and then descends to the southwest. Southeast of Saginaw near Blackmar and at Flint, the Marshall and the Berea are apparently much higher than to the east or west of these places. North of Saginaw, the Ralston well, sec. 4, T. 13 N., R. 4 E., and many other drillings for coal indicate a pronounced upward fold in the Coal Measures. The Marshall and the Coldwater also appear to be somewhat higher in the Page Oil & Gas Company's well (sec. 26, T. 14 N., R. 4 E.), than farther east along Saginaw river. At Kawkawlin, the brine horizons are between 700 and 800 feet deep, or considerably shallower than in Bay City to the southeast. Apparently this fold (Fig. 11), should run slightly west of north through Saginaw near Bristol street bridge to a point two or three miles west of Kawkawlin.

Southeast of Saginaw at Blackmar, the Marshall and the Berea occur in wells at 360 and 1545 feet, and at Flint 170 and 1200 feet respectively. As these formations are known to occur at greater depths east and west of these places, it appears that the anticline turns southeast toward Blackmar and Flint, but the evidence is not conclusive as the records of the drill holes at these places are of doubtful accuracy. As the Marshall appears to be only about 360 feet deep at Blackmar, 610 feet at Saginaw, and about 700 feet at Kawkawlin, the structure apparently pitches gently to the north. On the whole, the evidence seems fairly conclusive that a pronounced anticlinal fold exists in the strata down to the Marshall at least, and presumably much deeper, but its exact position and course are not so clearly indicated. Explorations of the Saginaw Valley Development Co. tend to prove the general correctness of this conclusion.

THE EXPLORATIONS.

The company spent some time in obtaining reliable contractors and made careful preparations to do the exploratory work in the most accurate and scientific manner possible. Ten wells were drilled, two to the Traverse, and the other eight to the Dundee. Accurate records were kept and full sets of samples taken for the Michigan Geological Survey, and the resulting information concerning the underlying rock strata in Saginaw Valley nearly to the base of the Dundee may

be considered as the most reliable and complete that has ever been obtained from any one set of deep holes drilled anywhere in Michigan.

Mundy-Fifield Well. The first well drilled by the Saginaw Valley Development Company was located near the S. E. corner of the N. W. $\frac{1}{4}$ of sec. 27, T. 13 N., R. 5 E., Buena Vista township, Saginaw county, although from the evidence then at hand, this location was four or five miles east of the axis of the supposed anticline. In this well, known as the Mundy-Fifield, the Marshall sandstone was struck at 780 feet, or 40 feet higher than in the South Bay City (North American Chemical Co.) well to the north in sec. 5, T. 13 N., R. 5 E., but fully 170 feet lower than the supposed depth to the Napoleon at the Old Wylie well on Niagara street about 800 feet north of Bristol street bridge.

The Berea was struck at 2070 feet, or 30 feet higher than in the South Bay City well. All of the formations from the Marshall down were found to be higher than corresponding ones in the Bay City wells, but much lower than at Saginaw, as shown by later drillings.

The Berea yielded some brine and a little gas, but no sign of oil. At the depth of 2246 feet the drilling was abandoned, but later in the spring of 1913 it was deepened to the Dundee, no noteworthy quantities of either oil or gas being struck anywhere. The Traverse and the Dundee were struck at 2513 and 3130 feet, or 100 and 140 feet higher respectively than in the South Bay City well, and about 230 feet lower than in the Saginaw wells.

Garey-Casamer No. 1. Another well was drilled near the site of the Wylie Bros. well on what is known as the Garey-Casamer lease. (Pl. II). The Upper Marshall, or Napoleon, was encountered at 610 feet, or 170 feet higher than in the Mundy-Fifield well, and 210 feet higher than in the well in South Bay City. The Berea was encountered at 1833 feet, or 233 feet higher than in the Mundy-Fifield well, and 265 feet higher than at South Bay City. It is to be noted from the foregoing records that the fold becomes more pronounced with depth.

As in the Mundy-Fifield well, the Berea proved to be a small yielder of brine, perhaps 25 barrels per day, and gas. Drilling was continued with the intention of going down to the Dundee, supposed to be 900-1000 feet below. At 2305 feet the Traverse formation was entered and oil of the highest grade was struck at 2317 feet in a sandy or cherty limestone. The so-called "sand" since called the "Saginaw sand," was very thin, probably being not much over two feet thick.

According to statements of officials of the company, the well made two flows of some 40 or 50 barrels of oil altogether. The indications were that a 25 to 30 barrel well had been struck. The well was shot

with 100 quarts of nitroglycerine. As soon as pumping began, however, it was found that the casing was leaking, and after the first 75 or 80 barrels, the production of oil fell off rapidly until the well yielded only about three or four barrels of oil per day with about 25 barrels of water. After much trouble, the water was finally shut off by the use of rubber packers, but the production was not materially increased. Finally the well was reshot with 20 quarts of nitroglycerine, but the casing was loosened so that water was again troublesome. After continuous pumping for some months without increasing the production, the well was pumped only intermittently with the Jackson-Church and the Cresswell wells in the same vicinity, the production finally decreasing to almost nothing.

Jackson-Church Well. The next well, No. 3, was drilled on the Jackson-Church property near the west end of Bristol St. bridge on Niagara St. and about 600 feet west of south from the Garey-Casamer well. The Marshall, Berea, and the Traverse were struck approximately at the same depth as in the latter well, but no sandy limestone or oil "sand" was found at the top of the Traverse. The "Saginaw sand," as the oil horizon in the Garey-Casamer well is called, appeared to have pinched out, and there was not the slightest show of oil or gas at this horizon.

The well was drilled to the Dundee, which was struck at about 2900 feet. At 2935 feet, there was a show of oil, but the largest was between 2945 and 2955 feet. The drilling was stopped at 3080 feet, after striking brine, which was plugged off and the well shot with 120 quarts of nitro-glycerine. The first pumping is said to have yielded some 50 barrels of high grade oil, and then the production rapidly fell off to about 2 or 3 barrels per day. Later this well, like the Garey-Casamer, was pumped but intermittently.

Cresswell Well. A fourth well was drilled about 1200 feet south of east from the Garey-Casamer No. 1, at the east end of Bristol street bridge on the Cresswell property. The formations were found to be, as in the Jackson-Church and Garey-Casamer wells, at approximately the same depth. In the Cresswell well, a showing of oil was struck in the "Saginaw sand" of the Traverse, another about 100 feet lower, and a third toward the base of the formation. The oils from the second and third horizons were dark and heavy and of much lower grade. None of these showings were deemed worth testing and the well was deepened to 3060 feet, the Dundee being struck at 2886 feet and a showing of oil found above 2942 feet. The oil is high grade, being similar to that found in the Jackson-Church well.

Watson Well. The Watson well, or No. 5, 3068 feet deep, was drilled on the Watson farm near the S. E. corner of S. W. $\frac{1}{4}$ of section 17,

T. 12 N., R. 5 E., Buena Vista township, about a half mile east of the city near the intersection of the highway and the new electric railway from Saginaw to Bay City. There was a small show of gas in the Berea, but no sign of either oil or gas was reported in the Traverse. Oil was struck in the Dundee, but in such small quantity that, after standing six days, there was only a few quarts of oil in the well and about 180 feet of water. The well, which was abandoned without shooting was plugged to protect the Marshall brines from contamination, and also to prevent leakage of gas which escaped in a considerable though not commercially important quantity from the Berea. Strong brine from the Berea constantly flowed over the top of the casing in small stream.

The Upper Marshall, or Napoleon, was struck at 600 feet, or slightly higher than in the Bristol street bridge drillings. The Berea was struck at 1835 feet, or practically at the same depth, and the Dundee at 2928 feet or about 28 feet deeper. Apparently the structure at Saginaw is that of a structural bench or terrace for the upper formations, and an asymmetrical anticline for the lower, the western limb being very much steeper than the eastern which dips but 28 feet from the Jackson-Church to the Watson well, a distance of $2\frac{1}{2}$ miles. From the Watson well east to the C. W. McClure well, 3000 feet in depth, near Gera in section 8, Frankenmuth township, the strata seem to be nearly flat, since corresponding formations were reported to be at practically the same depths and very similar in character as in Saginaw. Farther east, the strata must rise, as at Reese, the Napoleon is less than 500 feet from the surface. The broad flat depression in the lower formations to the east of Saginaw evidently pitches toward the north and becomes a pronounced syncline, in the vicinity of Bay City since the Berea drops from a depth of 1850 feet in the Watson well to 2035 feet in the Mundy-Fifield well, and 2100 feet in the South Bay City well, and similarly the Dundee from 2928 feet to 3130 and 3270 feet respectively.

Green Point Well. The Green Point well or well No. 6, also known as the Globe-Blaisdell, is located on the Globe-Blaisdell property nearly opposite the East Saginaw waterworks plant, on the N. W. $\frac{1}{4}$ of section 2, T. 11 N., R. 4 E. This well is situated about $2\frac{1}{2}$ miles south southwest from the Garey-Casamer. All of the formations were found to be from 110 to 135 feet deeper than in the Bristol street bridge wells, the Napoleon occurring at 720 feet, the Berea at 1965, the Saginaw "sand" at 2450, and the Dundee at 3012 feet. No signs of oil or gas were noted, but the Dundee, which was penetrated 240 feet, yielded an abundance of brine near the bottom of the well.

Lawndale Well. The Lawndale, or well No. 7, was drilled near Lawndale on the L. Reincke farm in the N. E. corner of section 5, T. 12 N., R. 4 E., about six miles northwest of the Garey-Casamer well, and at about two or three miles west of the axis of the anticline. All of the formations were struck from 185 to 260 feet deeper than in Saginaw, showing a dip of from 40 to 60 feet per mile to the northwest from the Garey-Casamer. The Dundee was penetrated 112 feet without showing a sign of either oil or gas.

The Green Point and the Lawndale, together with the Saginaw Plate Glass Co. wells in West Saginaw, show that the strata from northern and northwestern Saginaw dip rapidly to the southwest and west, proving the correctness of the earlier conclusions that there is an anticlinal arch at Saginaw. Unfortunately, the wells are so located that they do not indicate its precise direction or probable extent. In fact, it is not positively known that it extends continuously northward toward Kawkawlin.

Garey-Casamer No. 2 Well. Since all the wells located at some distance from the anticline gave little or no sign of oil and gas and the wells near or on it yielded both, the company decided to locate the next wells as near the axis of the anticline as possible, but farther to the north. Garey-Casamer No. 2 well was drilled 500 feet north and east from the Garey-Casamer No. 1 to test out the extent of the Saginaw sand in that direction, the sand having pinched out 600 feet to the southwest in the Jackson-Church well. The formations were found to be practically at the same depth as in the other Bristol street bridge drillings, but the Saginaw "sand" in the No. 2 well proved to be hard gray cherty limestone, showing not the slightest sign of oil or gas.

The drilling was continued to the Dundee, which was struck at 2885 feet and yielded a small flow of oil, but after standing several days the well was tested with the bailer and it proved to be less promising than either the Jackson-Church or the Cresswell wells.

Mershon Well. Some of the records of the old salt wells in northeastern Saginaw give the depth to the bottom of the "salt," that is to the red horizon marking the base of the Upper Marshall. After the first few wells had been completed by the Saginaw Development Company and the average thickness of this formation determined, it was possible to calculate the depth at which the top of the Upper Marshall should be struck in northeastern Saginaw. According to calculations, the top of the formation should be struck from about 605 to 615 feet below the surface in this part of Saginaw, or practically the same as in the Bristol street wells. It was also reported that one of the brine wells of Eastman & Co. was only 585 feet deep. This data indicated

that the crest of the supposed anticline was slightly to the east of the Wylie well, and upon this supposition the next, or No. 9, well was located near Saginaw river on the Mershon property about two miles north of the Bristol street wells and about 1000 feet north of the Pere Marquette railroad bridge.

The top of the salt formation was struck at 600 feet, or slightly higher than in the Garey-Casamer wells. The well was drilled to the Dundee, but no noteworthy amount of oil or gas was found at any horizon.

Ring Well. The Ring or No. 10 well was drilled on the C. L. Ring property a few hundred feet north and west of the Garey-Casamer well No. 1 to determine whether or not the "Saginaw sand" extended in that direction. This, the last well to be drilled, was a dry hole and apparently proved that the so-called "Saginaw sand" is very limited in extent and porosity, and that it holds little promise of containing any considerable quantity of oil and gas.

The almost absolute failure of these last wells, together with the great outlay of money already made, caused the company to abandon further exploration and to surrender their large lease holdings. It is to be regretted that more of the drill holes were not spaced along the supposed course of the anticlinal. Five of the ten wells drilled by the Saginaw Valley Development Co. were within a radius of 1200 feet, and three of the remaining five were at considerable distances from the supposed crest of the fold. In short, only about two miles of the anticline, apparently 25 or 30 miles long, has been tested, and this is not sufficient to determine whether the drillings are located in a sag or on a dome, if these secondary structures exist. Since oil and gas occurs in greatest abundance in the vicinity of the domes or cross arches it is possible that, had the explorations been made along the supposed axis of the anticline, oil and gas would have been found in greater quantity.

Gera Well. Chas. W. McClure, a prominent stockholder in the Saginaw Development Company, drilled a well 3000 feet deep near Gera on one of his farms, section 8, Frankenmuth township. According to the driller, the formations were encountered at about the same depths as in Saginaw and the well was "absolutely dry." The Marshall yielded such a strong artesian flow of brine, that drilling operations were stopped for some time.

A comparison of the records (Fig. 12) shows that the formations are remarkably regular in character and thickness. This is so true that, given the top of the Napoleon, the depths at which the Berea, Traverse, and Dundee should be struck can be calculated very closely. The error in calculating the depth of the Dundee in the Jackson-Church

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and the Green Point wells proved to be less than 10 feet. From a comparison of the records of the Braun (Mt. Pleasant No. 2), Gladwin, Bay City, and Saginaw wells, this uniformity in character and thickness of the formations seems to prevail over most of the central basin. The only formation which changes markedly is the Berea sandstone, which disappears toward the west side of the Basin, or is represented by red or sandy shales. Apparently, the Antrim shale grows thicker as the Berea thins and it has more or less white or blue shale near the top. The thickness of the black shale series from the top of the Sunbury (base of Coldwater) to the base of the Antrim is very uniform in all of the wells in the Central Basin.

THE OIL HORIZONS.

The Berea. From the date assembled before drilling began, it appeared that the Berea was the most promising horizon to test for oil and gas. In the South Bay City well there were strong signs just above this horizon, and in the Blackmar well considerable gas was encountered. A favorable structure seemed to be the only condition lacking for an accumulation of commercial size. It was a keen disappointment when the Berea yielded no oil and only a small quantity of gas which, however, increased considerably with time. In some wells, the gas was not noticed for some time after the brine was cased off. The latter, though apparently very strong, was also deficient in quantity, there rarely being a flow of much more than 25 barrels per day. In the Garey-Casamer No. 2, however, it was over 15 barrels per hour.

For some time, it was a puzzle why this formation did not consistently yield a greater abundance of brine, since it was so thick and well represented. An examination of the samples showed that the Berea is a very fine and close grained gray to white sandstone. In some phases, the sand grains are too fine to be readily distinguished by the naked eye. It is this fine to exceedingly fine grain of the rock which not only limits the flow of brine but also that of gas. A heavy charge of nitroglycerine might possibly increase the flow of gas greatly, but the head of brine probably would overcome it.

The "Saginaw Sand." The so-called "Saginaw sand" in Garey-Casamer No. 1 well appears to be a sandy or cherty limestone. There seems to be some doubt as to the exact nature of the oil horizon, but all of the samples examined by the writer proved to be limestone, commonly cherty or sandy, effervescing very vigorously in cold dilute acid and leaving a comparatively small residue of sand and chert. In any case, the productive "sand" is thin and pinches out wholly to the southwest in the Jackson Church well, to the northeast in the Gary-

Casamer No. 2, and to the northwest in the Ring well. In the Cresswell, or No. 4 well, this horizon is represented by two "sands"; that is, two cherty limestones separated by a shaly layer. In the Watson well, there is a cherty or pyritous limestone filled with black micaceous particles from 2325 to 2359 feet, but it contained no oil.

The Dundee. The Dundee oil horizon appears to be about 35 feet below the top of the formation and is a light gray to buff and brown granular limestone, effervescing violently with dilute hydro-chloric acid. A fragment shot out of the Jackson-Church well is a gray granular porous limestone, the pores being readily seen by the naked eye. The oil horizon appears to be free from water but there is an abundance of water a short distance below it as shown in the Jackson-Church, the Watson, and the Green Point wells.

EXPLORATION.

Of the eleven deep wells in the Saginaw field, six (Nos. 2, 3, 4, 8, 9 and 10), appear to be on the anticline and four of these six, perhaps significantly, yielded oil and gas in considerable if not commercially important quantities at two different horizons. In the Cresswell well, four oil bearing horizons were struck. The other wells are located from about one-half to three or four miles distant from the apparent crest of the anticline and yielded little or no oil and gas. The Watson, or No. 5, perhaps may be excepted as this well yielded considerable gas at the Berea horizon, but this well apparently is less than half a mile east of the axis of the anticline. Since the wells at some distance from the anticline have been so barren of encouraging results, it seems logical that future prospecting should be along the supposed axis of the structure. Oil may not be found in commercial quantity along its crest, but the chances are presumably greater in its immediate vicinity (especially near cross arches or domes, if they exist), than elsewhere.

In this connection, it must be borne in mind that the evidence pointing to the continuation of the anticline northward from Saginaw is not conclusive. Further drilling may show that the indicated anticline west of Kawkawlin between Bay City and Midland may have no direct connection with the one at Saginaw. The local structures in Saginaw Valley may be very different than is indicated.

Conclusions. In conclusion the following statements concerning the conditions for the occurrence of oil and gas in Saginaw Valley appear to be warranted from the evidence afforded by the wells of the Saginaw Valley Development Company, and wells of earlier date.

(1) A pronounced anticline undoubtedly exists at Saginaw and appears to be continuous northward to a point a few miles west of Kawkaw-

lin. (2) An equally marked syncline underlies the vicinity of Bay City. (3) The structure, as originally worked out by Dr. Lane, appears to be essentially correct, though future drillings may show that the structure at Kawkawlin is not continuous with that at Saginaw. The evidence on this point is not conclusive. (4) The various formations are remarkably uniform in character and structure. (5) There are at least three well represented and accessible oil or gas formations, and five possible oil horizons, three being in the Traverse. (6) All of the oil or gas formations contain oil or gas in small to considerable amounts, and from a geological standpoint, these products should occur in greater quantity at some point or points (the domes or cross arches) along the Saginaw anticlinal. (7) The indicated anticline appears to be 25 or 30 miles in length, and therefore the half dozen drill holes on its crest in the vicinity of Saginaw have tested only a small portion of the supposedly favorable territory.

CHARACTER AND COMPOSITION OF THE OILS.

The "Saginaw" Oil. The oil from the Saginaw "sand" is a very high grade paraffin oil, testing 47° Baume and containing over 62 percent of naphtha and burning oil. In color, it is light green by reflected light and deep red by transmitted light. The following analysis by the Paragon Refining Company of Toledo, Ohio, is indicative of the excellent quality of the oil.

Test of Petroleum from the "Saginaw sand," Garey-Casamer well No. 1:

Gravity of crude.....	47° Baume.
Naphtha.....	28.16%
Burning oil.....	34.5
Intermediate.....	8.66
Wax distillate.....	22.8
Tar.....	3.23
Loss.....	2.65
Total.....	100.00%

The black heavy oils found lower down in the Traverse were not tested.

Dundee Oil. The oil from the Dundee is high grade, testing 36° Baume, considerably lower than that from the "Saginaw" sand. The oil is green in color and has a distinct smell of sulphur. Preliminary tests show that it contains a considerable amount of this substance, but no complete analysis is available.

CHAPTER VI.

CENTRAL MICHIGAN.

GEOGRAPHIC AND GEOLOGIC RELATIONS.

The central district of Michigan includes the Saginaw oil field, which has been deemed worthy of a separate discussion in the previous chapter. The central district is not only near the geographic but also the geologic center of the Southern Peninsula. The deepest part of the Michigan Basin is in the region of Isabella and Midland counties. In the immediate vicinity of the center of the Basin the Berea is 2000 feet or more below the surface. The Dundee is nearly 3700 feet below the surface at Mt. Pleasant, therefore the Trenton should be more than 5500 feet (Fig. 1) in depth at this place.

Surface Deposits. Northwest of a line from Midland to Grand Rapids, the drift is very thick, ranging from 250 to 600 feet. From Bay City, southwestward past Midland to Alma and thence northwestward to Manistee there is an old preglacial rock valley which accounts for the great depth of drift at Alma, St. Louis, White Cloud and Mt. Pleasant.

In the southeastern portion of the central basin, the drift is relatively thin, and, from Grand Rapids and Holland southeast to Jackson and beyond, bed rock in many places is at the surface or under a very thin cover of drift. From Jackson to Huron county the drift is generally less than 150 feet thick, and in much of the region rock can be reached from 40 to 100 feet below surface.

EXPLORATIONS.

The great depth to the oil horizons and the thick drift in the northwestern half of the central district have been most effective in discouraging explorations for oil and gas. Deep drillings, however, have been made at Bay City, Midland, St. Louis, Alma, Gladwin, Mt. Pleasant, Grand Rapids, Charlotte, Delta, Eaton Rapids, Jackson, and near Morrice and Fowlerville, and at Ionia, St. Johns, Ithaca, Owosso, Durand, Perry, Blackmar and Flint.

BAY COUNTY.

Bay City. In North Bay City three or more deep wells have been drilled. One was bored by John Mason in 1885-6 to the depth of 2900 feet. The record indicates that the formations are about the same depth as in South Bay City, but that they are considerably different in character. The Coldwater apparently contains a number of limestone lenses, with a little black shale and sandstone at some distance above its base. The abundance of limestone in the Coldwater is unusual in the eastern part of the State, and possibly these "limestone" beds are only large iron carbonate concretions, which are common in this formation. C. E. Wright quotes John Mason as stating that the well at 2900 feet was in the same rock as the Morley well (Chap. IV) just north of Marine City. This indicates that the well may have been deeper than given in the record, and it is very probable that the record, which is only the driller's, is imperfect.

Brine was struck in the Parma, the Marshall, in the base of the Coldwater, and in the Berea. According to Cooper marked signs of oil or gas were observed at one or more horizons, but no mention of this is made in the record as originally published.

The Hall well (No. 93½ of the Saginaw Board of Trade map), was close to the above well but it only penetrated the Berea. Another well, MacLeans, was on the east side of the river near 28th street.

NORTH BAY CITY WELL.

Loc.: Near Atlantic Mill, North Bay City. Drilled in 1885-6 by John Mason. Record by Lane from notes of C. E. Wright and from record published by Bay City Tribune.

Elevation 592 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand and clay	85	85
Hard pan	35	120
Saginaw Coal Measures:		
Blue shale	300	420
Sandy shale	145	565
Parma:		
Limerock to brine 85°. Carboniferous limestone (?)	20	585
Sand rock; brine 45 ft. to 55 ft.	50	635
Grand Rapids Group:		
Sandy shale	25	660
Blue shale	40	700
Gypsum; white; 6 in. casing to 722 ft.	12	712
Blue shale	108	820
Hard limerock	10	830
Napoleon or upper Marshall:		
Sandstone; brine to 100°	90	920
Lower Marshall:		
White shale	35	955
Red shale	100	1055
Coldwater:		
Blue shale	50	1105
Limestone	40	1145
Hard blue shale	75	1220
Blue limestone (Calcareous shale?)	65	1285
White shale	105	1390
Sand shale	120	1510
Blue shale	20	1530
Hard limestone (Concretion?)	18	1548
Blue shale	200	1748
White shale	50	1798
Black shale	35	1833
Black limestone	65	1898
Brine bearing sandstone	15	1913
White shale	70	1983
Hard limestone	50	2033
Sunbury or Berea shale:		
Soft black sand	15	2048
Hard blue shale at 2067 ft.	45	2093
Black oily shale, 15-20 ft. thick at 2085 ft.		
Very hard limestone; 5 5-8 in. bore to 2120 and 5 1-2 in. below	25	2118
Berea:		
Sandstone	15	2133
Gray limestone	8	2141
Pumped clean sand at 2140 ft.		
Sandrock with salt brine; 100° overflowing top. (2252½ ft. deep, stopped in blue shale.—Wright).	165	2306
Antrim shale:		
White shale	65	2371
Black oily sandy shale	214	2585
Traverse (Hamilton) Formation:		
Black hard limestone	100	2685
Gray limerock	90	2775
Blue shale, quite hard	47	2822
Sandy limestone	30	2852
Limerock	13	2865

In December 1898, the deepest bore hole in Michigan excepting, however, the Braun well drilled in Mt. Pleasant in 1913, was begun at South Bay City by the North American Chemical Co. of Bay city. By February 22, 1899, the well was down to the Berea grit at 2100 feet. Drilling became more difficult and with a four months delay from a broken rope the well was not finished until in January of 1900. Careful notes of the drilling were kept and a complete set of samples

were preserved. From notes and samples, W. F. Cooper, of the Michigan Geological Survey, compiled the log¹ as given below.

NORTH AMERICAN CHEMICAL COMPANY WELL.

Loc.: South Bay City, sec. 5, T. 13 N., R. 5. E. Drilled by Thos. Percy.

Elevation 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand	15	15
Clay with thin seams of sand	35	50
Sand	10	60
Hardpan	10	70
Sand	30	100
Saginaw Formation:		
Shale	38	138
Quicksand, probably fissure	2	140
Sandstone	138	278
Blue shale	17	295
Sandy shale	10	305
Blue shale	15	320
Sandy shale	5	325
Blue shale	35	360
Shale	60	420
Fire clay	10	430
Blue shale	30	460
Fire clay	10	470
Shale	10	480
Red shale	10	490
Parma Conglomerate:		
Sandstone	50	540
Upper Grand Rapids, Maxville or Bayport:		
Brown dolomite	30	560
Silicious dolomite	60	610
Sandstone	10	620
Lower Grand Rapids or Michigan Series:		
Dolomite	5	625
Gray shale	25	650
Dolomite	10	660
Gray shale	35	695
Sandy dolomite	25	720
Green shale	10	730
Gray shale	10	740
Limestone	10	750
Gray shale	20	770
Limestone	10	780
Gypsum	10	790
Gray limestone	30	820
Upper Marshall or Napoleon Sandstone:		
Gray sandstone, brine	150	970
Analyzed. Usual temperature of brines 60.4° F.		
Lower Marshall:		
Red sandstone	100	1070
Blue shale	30	1100
Red shale	20	1120
Red sandstone	20	1140
Blue shale	45	1185
Red shale	5	1190
Coldwater shale:		
Blue shale	560	1750
At 1304 ft. 65° F.; at 1793 ft. 71° F.		
Dark blue shale	100	1850
Blue shale	70	1920
Red shale	20	1940
Blue shale	10	1950
Sandy shale	10	1960
Blue shale	100	2060
Sunbury (Berea) shale:		
Black shale	40	2100
Berea grit:		
Gray sandrock	40	2140
White sandrock, strong brine flowing over surface at 2170 ft. Flow about 20 gal. per hour at 2230 ft.	130	2270

¹Pl. II. Ann. Rept. for 1905, Bay County.

NORTH AMERICAN CHEMICAL COMPANY WELL.—Concluded.

Elevation 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Antrim shale:		
Blue shale.....	20	2290
Black shale, oily, gas.....	14	2304
Rock salt (from precipitation?).....	6	2310
Black shale, calcareous at 2380 and 2490 ft. (concretions?).....	225	2535
Brown shale.....	15	2550
Black shale.....	60	2610
Oil and gas at 2580.		
Traverse Formation:		
Sandy limestone.....	10	2620
Sandstone.....	10	2630
Blue shale.....	60	2690
Limestone.....	10	2700
Blue shale.....	27	2727
Limestone.....	9	2736
Sandstone. Brine with indications of gas (between 2734-2740 ft.).....	44	2780
Sandy limestone.....	30	2810
Brown sandy limestone.....	50	2860
Gray sandy limestone. Brine.....	45	2905
At 2934 ft. 90.1°-90.2° F.		
Pepper sandy limestone.....	35	2940
Blue shale.....	180	3120
Gray shaly limestone.....	40	3160
Blue shale.....	50	3210
Marcellus shale:		
Black shale.....	60	3270
Dundee limestone:		
Gray limestone (yellow limestone—Cooper.).....	238	3508
At 3455 ft. 97° F.		

The information furnished by this record was valuable in indicating the character, depth and thickness of the formations, and number and depth of the water bearing strata, and the possible oil and gas horizons which might be expected to be encountered in drilling in the vicinity of Saginaw.

In the South Bay City well, water or brine was struck in abundance in the Coal Measures, the Parma, and the Upper Marshall. A strong brine was found in the Berea, in the Traverse, and very probably a highly mineralized brine was struck in the lower portion of the Dundee, although the latter is not noted in the record.

Strong signs of oil and gas were noted just above the Berea grit, but in none of the lower horizons except the Upper Traverse were noteworthy signs reported. The well penetrated the Dundee limestone 238 feet and the bottom of the well is probably close to the top of the Monroe dolomites since the Dundee is not known to be more than about 250 feet thick in Michigan.

Kawkawlin. At Kawkawlin, northwest of Bay City, salt wells show that the Napoleon brine horizon occurs between 700 and 800 feet, or 150 to 200 feet higher than in Bay City. Since westward the same horizon is struck at Midland at 1205 feet a very strong fold must lie between Midland and Bay City. As noted on previous pages, the Saginaw anticline is conceived as running slightly west of north from Saginaw through a point two or three miles west of Kawkawlin. The

connection between the anticlinal fold at Kawkawlin and Saginaw seems probable since the Coal Measures also show a strong upfold in the Ralston well near the old Bay Mine No. 2. The Marshall and the Coldwater in the Page Oil and Gas Company (see Chap V) well also appears to be higher than they are farther east along Saginaw river.

FRANKLIN WELL.

Loc.: Kawkawlin, Bay County.

Elevation 596 ft. A. T.	Thick- ness, feet.	Depth, feet.
Drift.....	100	100
Saginaw Formation:		
Shale and sandrock with coal seams.....	300	400
Grand Rapids Group:		
Gypsum at 400 ft., limestone and gypsiferous shales.....	100	500
No record.....	200	700
Napoleon:		
Sandstone with a strong brine.....	100	800
Lower Marshall:		
Red shales.....	233	1133

The thicknesses as given in the above record are evidently approximations as they are in round numbers.

SAGINAW COUNTY.

Blackmar. In the early 70's, a well reported to be 1764 feet in depth was drilled at Blackmar, Taymouth township, Saginaw county. Considerable gas and a strong brine appears to have been struck below 1545 feet. As a coarse sandstone corresponding to the Napoleon was struck at 360 feet, the sandstone below should be the Berea. As mentioned in the discussion of the Saginaw oil field, this depth appears to be much less than to the east or west of Blackmar, hence it is supposed that south of Saginaw the anticline veers to the east and runs through Blackmar towards Flint.

The depth of the well is given as 1764 feet but the record only adds up to 1677 feet.

BLACKMAR WELL.

Loc.: Blackmar, Taymouth Twp., Saginaw County. Mr. Blackmar, owner.

Elevation about 613 ft. A. T.	Thick- ness, feet.	Depth, feet.
Drift.....	90	90
Shale.....	270	360
Coarse sandrock, brine 63° salinometer test.....	90	450
Blue shales.....	45	495
Red shales.....	200	695
Gray sandy shales.....	850	1545
Sandstone with a strong brine at 1675? (1545?) ft.....	110	1655
Gray shale.....	20	1675
Limestone.....	2	1677

GENESEE COUNTY.

Flint. At Flint there are many shallow borings, chiefly for coal. These indicate that the Maxville limestone is absent, probably eroded. In a deep well drilled many years ago a coarse sandstone was struck at 170 feet which yielded a "strong stream of sweet water." This, according to Lane, resembles the Marshall, and another sandstone at about 1200 feet containing a strong brine would therefore correspond to the Berea. The recent drillings for coal in the vicinity of Flint, however, indicate that the Marshall is more than 170 feet below the surface, hence the sandstone yielding the flow of fresh water is probably a sandstone belonging to the Coal Measures.

FLINT WELL.

Reported by Dr. Clark.

Elevation 715 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Drift.....	68	68
Sandstone.....	67	135
Shales and sandstone with seams of coal.....	35	170
Marshall:		
Sandstone, with a strong stream of fresh water at 260 feet.....	108	278
Alternations of shale and sandstone; in the lower part strong brine (from Berea?).....	922	1200

MIDLAND COUNTY.

Midland. At Midland, there are seven wells to the Marshall, which is struck at about 1200 feet or 580 feet deeper than at Saginaw. This represents a dip from South Bay City to Midland of about 20 feet per mile, and 30 feet per mile from Saginaw. The No. 1 was drilled for Larkin & Patrick in 1879. Others were drilled later for brominiferous brines by H. H. Dow and the Midland Chemical Company. The wells in the northwestern part of the city reach rock sooner than those in the southeastern part. The drift is much thicker than at Saginaw and Bay City but not nearly so thick as at Mt. Pleasant, Alma or Gladwin. Brine was struck in the Coal Measures, the Parma, and the Napoleon, the brine increasing in strength with depth. The record given below is representative of the character of the formations.

MIDLAND WELL.

Elevation 608 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface deposits.....	285	285
Coal Measures:		
Micaceous white sandstone, fresh water.....	33	318
Black soft shale.....	27	345
Sandstone, brine at 420 ft.....	65	420
Hard shale.....	35	455
Sandstone.....	70	525
Hard shale.....	50	575
Hard sandstone.....	7	582
Black shale.....	118	700
Calcareous (FeCO ₃) shale.....	45	745
Black shale.....	65	810
Parma:		
White sandstone.....	110	920
Grand Rapids:		
Argillaceous limestone.....	50	970
Plaster bed, fairly pure anhydrite.....	80	1050
Calcareous shale.....	80	1130
Limestone.....	75	1205
Napoleon or Upper Marshall:		
White sandstone somewhat ferruginous.....	100	1305

In the No. 13 well of the Dow Chemical Co. red shale occurs at 1390 feet or above. (C. W. Cook, Pub. 15, Geol. Series 12, 1913.)

GRATIOT COUNTY.

Alma. At Alma, one of the deepest wells in central Michigan was drilled in 1895 for the Alma Sanitarium. It reached a total depth of 2865 feet and was bottomed in the Upper Traverse limestones where mineral water with a temperature of 98° F, was struck. A little gas also seems to have been found in the top of the Traverse.

The drift was very thick, bed rock being struck at 500 feet. This is much deeper than at St. Louis and Mt. Pleasant. The Napoleon is about 375 feet higher than at Mt. Pleasant, thus indicating an abnormal dip of the formation from Alma to the north-northwest.

ALMA WELL.

Loc.: Alma Sanitarium, 1889. Sec. 34, T. 14 N., R. 3 W. Reported by Prof. C. A. Davis, from samples.

Elevation about 755 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Clay and gravel with quicksand and water at 60 ft. and 3 ft. water-bearing gravel at 157 ft.	475	475
Sand and gravel.	25	500
Woodville:		
Feldspathic sandstone (335-590 at St. Louis)	50	550
Coal Measures:		
Pyritiferous black shale, coal horizon.	25	575
Blue shale.	40	615
White shale.	22	637
Pebbly sandstone.	38	675
Shale sometimes black, coal reported.	35	710
Parma sandstone:		
Pyritic sandstone, brine.	80	790
Grand Rapids:		
Blue and black sandy shales.	70	860
Blue and white gypsum.	35	895
Bituminous, dolomitic red or blue argillaceous limestones (cement rock).	120	1015
Upper Marshall or Napoleon:		
Clean white sandstone, brine.	85	1100
Lower Marshall:		
Red sandy shale.	200	1300
Blue shale.	20	1320
Red shales.	180	1500
Coldwater:		
Blue shales.	75	1575
Brownish fine grained grit, no water.	30	1605
Black shales.	35	1640
Light yellowish fine sand.	40	1680
Dark shale colored limestone or shale.	60	1740
Dark blue shale.	510	2250
Berea shale:		
Black shale.	50	2300
Berea absent?:		
Antrim (Ohio shale):		
Blue shale.	60	2360
Black shale.	260	2620
Black shale with harder streaks (limestone shells?) Sandy from 2630-2670 ft.	130	2750
Traverse Formation:		
Dolomitic limestone.	30	2780
Blue shale.	20	2800
Sandy limestone, dolomitic.	61	2861
Mineral water at 2825 ft. Temp. 98° F.; gas.		

St. Louis. There are two or three deep wells at St. Louis which penetrate the Upper Marshall. The latter is reached at about 1330 feet and yields abundant brine. No definite records are available.

Ithaca. The Ithaca well, though not deep, has a carefully compiled record as published by a local newspaper. The drilling did not reach the Marshall and the 2 feet of light shale at the bottom of the well is probably the top of the Grand Rapids Group.

ITHACA WELL.

Record by the Gratiot Journal.

	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Surface clay.....	10	10
Blue clay, stony.....	70	80
Hardpan.....	38	118
Gravel.....	1	119
Hardpan.....	30	149
Gravel. Considerable water.....	2	151
Hardpan.....	40	191
Gravel.....	4	195
Blue clay.....	6	201
Hardpan.....	10	211
Gravel.....	2	213
Red clay.....	60	273
Hardpan.....	4	277
White clay.....	25	302
Blue clay.....	8	310
Hardpan. Very hard.....	10	320
Gravel.....	5	325
Hardpan.....	5	330
Woodville (?) sandstone:		
Gray sandstone. Very hard. Bottom of 8-inch casing.....	2	332
Gray sandstone.....	4	336
Saginaw Coal Measures:		
Fireclay.....	3	339
Red sandstone.....	4	343
Red shale.....	2	345
Blue shale.....	4	349
Bottom of 7-inch casing, with two 16 foot lengths, standing up into 8-inch pipe, 15 ft. bagged and swedged out on top. Bottom of this casing is 349 ft. by measurement.		
Blue shale.....	6	355
Limerock.....	2	357
Sandstone.....	5	362
Blue shale.....	5	367
Dark lime.....	1	368
White shale.....	15	383
Black shale.....	16	399
Light shale.....	15	414
Blue shale.....	20	434
Dark lime.....	6	440
Light shale.....	22	462
Dark lime.....	8	470
Sandrock.....	8	478
Dark lime.....	2	480
Sandrock.....	2	482
Light shale.....	8	490
Sandrock.....	25	515
Light shale.....	10	525
Parma:		
Light sandstone.....	86	611
Grand Rapids Group(?):		
Light shale.....	2	613

ISABELLA COUNTY.

Mt. Pleasant. In 1903, the city of Mt. Pleasant and the Midland Chemical Company drilled a well over 1550 feet deep penetrating to the lower Marshall, which was struck at about 1400 feet. This well indicates that the corresponding formations are from 200 to 600 feet deeper at Mt. Pleasant than at Alma, Midland, Bay City and Saginaw.

In 1913 W. F. Braun, an oil operator from the Pennsylvania and the Oklahoma fields drilled the deepest well in Michigan on the Riley farm near Mt. Pleasant in sec. 27, T. 14 N. R. 4 E. The record down to the top of the Traverse at 3082 feet is by Mr. Braun, but from that point his record has been supplemented by that obtained from an examination of a complete set of samples, which Mr. Braun kindly preserved and sent to the Michigan Geological Survey.

A comparison of the Alma and the old Mt. Pleasant well records with the new one shows that the rock formations are very similar even in many minor details. The depths to the Berea and the Dundee, however, are greater than calculated. In neither the Alma nor the Braun well is the Berea present in its typical phase as a sandstone. The "limestone and black sand" from 2568 feet to 2598 feet yielding oil at 2590 feet with a specific gravity of 47° Baume, may possibly represent this horizon. Some gas accompanied the oil. Another show of oil occurred in the Antrim black shales at 2632 feet.

In July the well reached the top of the Dundee at 3667 feet, but this formation yielded such a strong flow of water at 3675 feet that the well had to be abandoned at 3680 feet. Generally the upper portion of the Dundee does not yield much water.

Deep drillings at Bay City, Saginaw, Gladwin, Alma and Mt. Pleasant indicate a remarkable uniformity in the character and thickness of the formations down to and including the Dundee, therefore if the formations below the Dundee are as regular in thickness, the Niagara should be found at about 5100 feet and the Trenton at 6200 feet or more. Such depths are so great that the cost of testing the oil possibilities of either one of these formations is out of proportion to the chances for success.

MT. PLEASANT WELL.

(Mt. Pleasant Village and Midland Chemical Company.)

Loc.: 0.65 miles N., 2 miles west of S. E. Cor. of sec. 10, T. 14 N., R. 4 W. Record from samples and notes of A. Borden.

Elevation about 707 (?) ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or drift:		
Gravel, glacial overwash.....	80	80
Blue till.....	20	100
Quicksand.....	20	120
Blue till.....	160	280
Porous bed with water, coarse gravel on top, fine sand below.....	74	354
Red clay.....	26	380
Ground moraine, till with broken coal measures.....	55	435
Saginaw Coal Measures:		
Black shale with streaks of coal (410,435, 560 ft.), sandstone, limestone or carbonate of iron and fire clay, mostly less than five ft. thick.....	185	620
Fine white sandrock with mineral water.....	90	710
Gravelly sandrock, with a strong flow of water not so salt.....	80	790
Shale and red limestone.....	30	820
White limestone.....	30	850
Parma:		
White sandstone with very salt water.....	120	970
Marville:		
White limestone, fiercely effervescing.....	55	1025
Shale.....	5	1030
Sandstone.....	20	1050
Michigan Series:		
Dolomite and shale.....	75	1125
Anhydrite and dolomite.....	100	1225
Anhydrite, nearly pure (gypsum).....	45	1270
Dolomite, shale and anhydrite (gypsum).....	103	1373
Sandstone.....	8	1381
Shale.....	5	1386
Sandstone.....	4	1390
Shale.....	15	1405
Napoleon:		
Sandstone, dark, with heavy brine.....	145 +	1550 +
Lower Marshall, 1550 + ft.:		
Red rock; well originally 1463 ft. deep, afterwards deepened to be between 1550 ft. and 1585 ft., ending in red rock.		

W. F. BRAUN WELL.

Loc.: On Riley farm, Mt. Pleasant, Mich., W. $\frac{1}{4}$, N. W. $\frac{1}{4}$ of sec. 27, T. 14 N., R. 4 W.
 Driller's record to 3082 ft. Record supplemented by samples below this point.

Elevation given as 800 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand loam.....	2	2
Quicksand and water.....	16	18
Clay.....	32	50
Sand and water.....	8	58
Clay.....	2	60
Sandy clay.....	15	75
Quicksand vein, good water.....	1	76
Sandy clay.....	13	89
Quicksand.....	1	90
Sandy clay.....	10	100
Quicksand.....	10	110
Gravel.....	15	125
Gravel and quicksand.....	47	172
Blue fire clay.....	45	217
Gravel.....	5	222
Blue "fire clay".....	60	282
Red "sand rock" (boulder?).....	10	292
"Fire clay," blue.....	10	302
Red sand rock (boulder?).....	27	329
"Fire clay," pinkish color.....	41	370
Quicksand and water.....	5	380
Red "fire clay".....	10	390
Gravelly sand.....	10	400
Saginaw Coal Measures:		
Limestone.....	5	405
Red sand rock, hard.....	40	445
Fresh soft water.....	5	450
Sand rock red.....	3	453
Black slate (shale).....	10	463
Gray sand rock.....	10	473
Black fire clay.....	4	477
Gray sand rock.....	31	508
Black shale.....	25	533
Gray shaly limestone.....	10	543
Black shale.....	124	667
Pure white sand, fresh water.....	55	722
Red shale.....	30	752
White soapstone.....	24	776
Gray limestone.....	26	802
White shales.....	9	811
Parma:		
Pure gray salt sand, much brine.....	124	935
Maxville or Bay Port:		
Limestone gray, very hard.....	45	980
Mixed limestone, pebbly and sandy.....	35	1018
Michigan Series:		
Salt blue (shale?).....	3	1021
Mixed limestone.....	6	1027
Blue shale.....	11	1038
Mixed rock, blue shale and limestone.....	32	1070
Mixed rock gypsum and clay.....	35	1105
Gray limestone.....	10	1115
Blue shale.....	35	1150
Black shale.....	10	1160
Gray limestone.....	10	1170
White limestone.....	24	1194
Blue shale.....	6	1200
White limestone.....	15	1215
Blue shale.....	25	1240
Gray limestone, very hard.....	25	1265
Mixed limestone of rock and shale.....	35	1300
Gray limestone.....	10	1310
Blue shale.....	10	1320
Limestone, very hard.....	10	1330
Blue shale.....	10	1340
Fine gray sand (top of the Upper Marshall?).....	60	1400
Gray limestone.....	38	1438

W. F. BRAUN WELL.—Continued.*

Elevation given as 800 ft. A. T.	Thick- ness, feet.	Depth, feet.
Upper Marshall or Napoleon:		
Salt sand, gas, sand top; much salt water, 1535 ft. of 8½ in casing.....	69	1507
Lower Marshall:		
Red sand rock.....	75	1582
Coldwater:		
Blue shale.....	716	2298
Gray shell (carbonate nodule?).....	2	2300
Blue shale.....	15	2315
Gray shell (carbonate nodule?).....	3	2318
Blue shale.....	232	2550
Sunbury shale:		
Brown shale.....	18	2568
Limestone.....	4	2572
Brown shale.....	6	2578
Berea (?) horizon:		
Black sand and shale, showing oil and gas; oil of Sp. gravity of 47°, at 2590 ft.....	20	2598
Antrim shale:		
White shale.....	18	2616
Brown shale.....	40	2656
Black shale.....	20	2676
Black sand and shale small show of oil; hole reduced to 6½ inches.....	6	2682
Black shale.....	233	2915
Black sand, mixed with black shale; mineral ore showing silver (?) and iron ore.....	13	2928
Black shale.....	54	2982
Black sand, mixed with black shale, showing mineral ore, silver (?) and iron.....	13	2995
Black shale, mixed with limestone.....	15	3010
Black shale.....	72	3082
Traverse (Hamilton) Formation:		
Salt and pepper limestone; mod. eff. Very little chert. Some particles of black shale from above at 3082.		
Light grayish buff limestone.....	2	3084
Buff gray limestone, mod. eff. Slightly cherty.....	2	3086
Grayish buff limestone, pyritic, a little chert; briskly eff.....	2	3088
Gray limestone, briskly eff.....	5	3093
Dark buff gray limestone, mod. eff.....	6	3099
White and dark gray limestone, pyritic; vigorously eff. Some dark gray shale; calcite crystals.....	6	3105
White crystalline limestone and very calcareous shale; some pyrite; vigorously eff.....	6	3111
Very calcareous blue shale.....	17	3128
Light gray to dark gray limestone; brisk eff.; calcite fragments.....	15	3143
Light gray limestone and dark gray shale; brisk eff.....	7	3150
White to light gray limestone; brisk eff.....	7	3157
Yellowish gray limestone; violent eff.....	13	3170
Very cherty white limestone.....	18	3188
Very cherty fossiliferous (coral, acervularia?) limestone; blue and black shale; violent eff.....	6	3194
Very cherty fossiliferous (coral) light gray limestone; violent eff.; some blue shale.....	6	3200
Very cherty light gray limestone, pyritic with some blue shale.....	6	3206
Very fine white cherty limestone; violent eff.....	4	3208
Cherty white crystalline limestone; violent eff.....	2	3210
Yellowish white and very cherty limestone; violent eff.....	2	3212
White to light gray cherty limestone; violent eff.....	6	3218
Very cherty white fossiliferous limestone; violent eff.....	12	3230
Fine grained cherty white limestone; violent eff.....	4	3234
Buff gray limestone; violent eff.; some dark shale.....	6	3240
White to light gray cherty limestone; very hard; violent eff.....	5	3245
Same.....	15	3260
Light gray limestone; violent eff.....	16	3276
White limestone; violent eff.....	20	3296
Light gray with some black limestone and dark gray shale; violent eff.....	4	3300
Light and dark limestone ("salt and pepper"); violent eff.; some gray shale.....	6	3306
Dark gray limestone.....	6	3312

• W. F. BRAUN WELL.—Concluded.

Elevation about 800 ft. A. T.	Thick- ness, feet.	Depth, feet.
Traverse (Hamilton) formation:		
Gray limestone, violent eff.	25	3337
Salt and pepper limestone.	13	3350
Buff white limestone mixed with some shale.	25	3375
Buff gray limestone.	9	3384
Light limestones and dark to black shaly limestone.	4	3388
Gray limestone mixed with some light limestone.	12	3400
White and gray limestone; violent eff.	15	3415
Buff gray limestone mixed with some dark; violent eff.	12	3427
Hard white to light gray limestone; violent eff.	3	3430
White limestone mixed with gray.	42	3472
Salt and pepper limestone.	8	3480
Gray shale; mixed with limestone at 3480.		
Calcareous gray shale.	24	3504
Very calcareous light gray shale.	2	3506
Calcareous bluish gray shale.	10	3516
Dark bluish gray shale mixed with light gray limestone.	6	3522
Dark bluish gray shale.	11	3533
Calcareous gray shale and limestone.	25	3558
Calcareous and fossiliferous gray shale.	22	3580
Very dark gray, cherty and fossiliferous limestone and dark calcareous shale.	8	3588
Cherty limestone mixed with shale.	10	3598
Bluish shaly limestone; some chert; very hard.	22	3620
Dark buff gray limestone and black shale; mod. eff.	47	3667
Dundee limestone:		
Very hard buff to dark gray limestone; cherty and very pyritous; mod. eff.	8	3675
Very hard, dark buff pyritous limestone; mod. eff.	5	3680

So strong a flow of water was struck at 3675 ft. that drilling was stopped at 3680 ft. Temperature at bottom 104° F. Temperature gradient apparently one degree in about 67 ft.

GLADWIN COUNTY.

Gladwin. A very deep well was drilled in 1913 at Gladwin for oil by Chas. G. McClure of Saginaw. According to the records of wells in the vicinity of Gladwin rock is from 200 to 400 feet, below the surface but, in the McClure well, the drift was found to be 600 feet in depth and great difficulty was encountered in getting the drive pipe down to rock. Much quicksand and water was found in the drift.

The elevation of this well is not known, but it appears to be about 780 feet above sea level, or nearly 200 feet higher than the Saginaw wells. Mr. McClure, having drilled one well near Gera in Saginaw county and striking the Dundee between 2900 and 3000 feet, inferred that this formation should be struck at about the same depth at Gladwin. The Gera well is on the flat, eastern limb of the Saginaw anticline, and therefore the Dundee is 100 to 150 feet higher than it would be if the normal dip prevailed.

Since Gladwin is 200 feet higher and is not on an anticline, the depth to the Dundee should be several hundred feet greater than in the Gera well, and apparently this is the case. In May, the well reached the depth of 3043 feet, having penetrated the Traverse formation less than 100 feet and operations were temporarily suspended as the normal capacity of the drilling outfit had been exceeded. According to reports another drilling rig was brought in, but on account of the small hole, or other difficulties, the well was abandoned without reaching

the Dundee oil horizon. Since the Traverse in the central part of the Basin is everywhere about 600 feet thick, the Dundee at Gladwin should be struck between 3550 and 3600 feet.

The record was made by the writer from a hasty examination of a set of samples in Mr. McClure's office. The exact thickness of the various strata could not be determined from the data accompanying the samples, hence the record is more or less indefinite.

Assuming that the elevation of the Gladwin well is about 50 feet higher than the Braun well, the dip of the Napoleon from Gladwin to Mt. Pleasant is only about 5 or 6 feet per mile.

McCLURE WELL.

Loc.: Near Gladwin. Chas. G. McClure, owner; drilled in 1913.

Elevation about (?) 790 ft. A. T.	Depth, feet.
Surface.....	600
Sand with water at 380 ft.	
Saginaw Coal Measures:	
Dark gray shale.....	600
Parma:	
Sandstone.....	650
Grand Rapids Group:	
Calcareous green shale.....	790
Dark gray shale with considerable gypsum.....	945
White sandstone with brine.....	950
Light gray limestone and shale.....	1020
Shaly limestone with gypsum.....	1030
Dark limy shale.....	1190
Gray shale with pyrite, gypsum and brine.....	1230
Napoleon at:	1250
White sandstone, with some limestone fragments, pyrite and brine.....	1300
Lower Marshall:	
Red sandy shale.....	1350
Coldwater shales:	
Dark gray shales..... (1425 ft. to)	1675
Gray shales.....	2150
Richmondville? sandstone:	
Extremely fine grained light gray sandstone, somewhat calcareous, full of small black specks.....	2170
This sandstone resembles very closely some of the Berea found at Saginaw, but it appears to be too high for the Berea and may be one of the stray sandstones often found in the Coldwater shales at some distance above its base.	
Light gray shales..... (2205 ft. to)	2275
Dark gray shales but not bituminous at.....	2350
Antrim:	
Very black and bituminous shale at.....	2495
Light gray shale.....	2465
Brownish black bituminous shale..... (2525 ft. to)	2825
Light gray and brownish shale, mixed.....	2880
Both black and brown shale, more or less calcareous.	
Very pyritic black shale with some white chert fragments.....	2900
Very pyritic black shale with some white chert fragments.....	2940
Traverse (Hamilton) Formation:	
Top probably at about.....	2970
Light gray limestone with some black particles of shale, probably from the black shale above.....	2975?
A sample was missing between 2940 and 3025 ft. and this bottle without a label appears to be the missing sample which probably was taken not far from 2975 ft. The top of the Traverse, therefore, should be between 2940 and 2975 ft. and from the amount of black particles in the sample, the top may be nearer 2975 ft.	
Gray limestone fiercely effervescent.....	3025
Some particles of black shale in this sample, probably from above. These were also calcareous.	
Light gray limestone, fiercely effervescent, cherty and granular. The limestone breaks up into very fine particles.....	3035
Light gray limestone, fiercely effervescent, cherty and granular. The limestone breaks up into very fine particles.....	3040
Cherty light buff limestone, moderately effervescent.....	3043
Well afterwards deepened but amount unknown.	

MECOSTA COUNTY.

Big Rapids. Near Big Rapids a well was drilled to the depth of 1400 feet by A. L. Clark a number of years ago. This well, known as the Red Cross well, entered rock at 600 (?) feet and struck water at 600, 800, 850 and 1300 feet. The brine at 1300 feet is very strong, and is probably from the Marshall. No record of the well is available.

KENT COUNTY.

Grand Rapids. The Grand Rapids Artesian Well Co. sunk a well for water to the depth of 2220 feet. An abundance of fresh water was found in the Upper Marshall sandstone, but it did not flow. Weak brines were struck in the Lower Marshall, mineral water in the Coldwater, a stronger brine from a sandstone in the lower part of the Coldwater, and gas and brine in the top of the Dundee. The black shales of the Antrim yielded a strong smell of gas and oil.

GRAND RAPIDS WELL.

Grand Rapids Artesian Well Co. Record by C. E. Wright.

Elevation between 605 and 639 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene or Surface:		
Drift.....	10	10
Grand Rapids Group:		
Black clay slate.....	47	57
Plaster rock (gypsum) mixed with clay slate.....	71	128
Marshall Sandstone:		
Sandstone, dark and light colored.....	17	145
Sandstone, light gray. Fresh water, increases with depth.....	95	240
Lower Marshall:		
Hard black coarse sandstone. Increase of fresh water.....	19	259
Blue clay slate.....	12	271
Ash-colored sandstone, mixed with clay seams and layers of soapstone; fine texture. Small quantity of weak brine, 20°.....	129	400
Coldwater shale:		
Sandy shales at top and clay-rock boulders and sheets below.....	20	420
Light blue to ash-colored shale, with very little change in color except for short places which are little darker. Quite uniform as to hardness. Except these (?), the lower 250 ft. has more hard streaks, and boulders that would make slate pencils.....	735	1155
Dark hard water-lime from 702 to 712 ft. There is a streak of ten feet from 712 to 722 ft. of calcareous water-lime, dark and hard at top and softer below; but it is all hard rock.....		
Dark red clay, soft.....	20	1175
Sandstone, (Richmondville?) brine 26°, small amount.....	30	1205
Light to greenish blue shale, mixed with clay rock. Streaks and boulders and streaks of gas-scented material.....	295	1500
Antrim shale:		
Black slate rock; scent of gas at top and stronger in depth and very strong at bottom.....	208	1708
Black slate or hard rock; strong odor of gas and oil.....	67	1775
Traverse (Hamilton) Formation:		
Drab limestone; color changes nearly every foot.....	52	1827
Drab magnesian limestone.....	28	1855
Very dark water-lime.....	10	1865
Each screw changes color.....	20	1885
Limestone; light gray and medium hard in upper portion and dark drab and hard below.....	115	2200
Gas, marl, limestone and brine.....	20	2220

IONIA COUNTY.

Ionia. A comparatively shallow well was drilled near the old sandstone quarries at Ionia many years ago. While it penetrated no oil horizon, the record is inserted as there are so few drillings in this part of the State giving any reliable information concerning the underlying rocks.

IONIA WELL.

Loc.: In vicinity of old sandstone quarries. Record by Mr Blanchard.

	Thick- ness, feet.	Depth, feet.
Saginaw Coal Measures:		
Sand rock	95	95
80 to 110 ft. in thickness.		
Shales and fire clay	4	99
Coal from 20 in. to 4 ft. at 99 ft.		
Fire clay	2	104
Sand rock, fine grained	40	144
Coal seam, thickness unknown		
Sandrock and shales alternating	306	450
"Copious stream of sweet water at 300 ft." Record not accurate in some places.		

BARRY COUNTY.

Assyria. In 1899 a well was drilled near Assyria (sec. 14, T. 1 N., R. 7 W., about 870 A. T.) but no record is obtainable. According to the driller, John Brogan, the bottom of the Antrim black shale was struck at 1875 feet. In 1903, another well was drilled at Assyria from which a good set of samples was preserved for the Survey by G. D. Connor and J. J. Callender. The latter located the well with an "instrument," but no oil was found, although the well passed through the Dundee. Apparently the well was deepened in the spring of 1904 from 2040 to over 2300 feet, but no record was obtained of the lower part of the drilling.

ASSYRIA WELL.

Loc.: Sec. 9, Assyria Twp.

Elevation 917 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or Surface:		
Soil.....	2	2
Sand and gravel.....	38	40
Clay and gravel.....	15	55
Quicksand with water.....	7	62
Sandy clay.....	34	96
Fine sand, clay and gravel.....	34	130
Clay and gravel.....	32	162
Michigan Series:		
Limestone, light colored dolomite.....	1	163
Bluish shale and gypsum.....	77	240
Napoleon or Marshall:		
Clean white sandstone with water. Came within 100 ft. of top of well..	70	310
Dark sandstone.....	10	320
Lower Marshall:		
Soft blue shale with "heavy black sand".....	110	430
Calcareous shale and fine gray sandstone.....	20	450
Bluish shale, fine and sandy.....	50	500
Coldwater shale:		
Dark gray shale, very fine grained.....	575	1075
Typical Coldwater.		
First showing of oil at 560 ft. and water at 900 ft. Brown shale at 1075 ft. is iron carbonate.		
Dark green shale, calcareous.....	325	1400
Berea horizon:		
Red shale. Typical Bedford.....	50	1450
Antrim shale:		
Black and bituminous shale.....	18	1468
Dark blue shale.....	57	1525
Very black and bituminous shale, smell of gas.....	175	1700
Very black in part. Smell of gas or ammonia.....	55	1755
Pyritic and not as calcareous as above.		
Gray shale, hard and calcareous.....	15	1770
Very black and pyritic shale.....	40	1810
Traverse (Hamilton) Formation:		
Brown limestone fiercely effervescent.....	50	1860
Dark and shaly looking.		
Very black shale, very pyritic and quite calcareous. No water below 1875 ft.	15	1875
Dundee (Corniferous) limestone:		
Buff limestone, fiercely effervescent.....	65	1940
Cherty limestone, brownish fiercely eff.	35	1975
Pure white limestone, little or no chert, fiercely eff. Brine at 2000 ft., 93° salinometer test.....	35	2010
Dark brownish tending to drab limestone, fierce eff.	15	2025
Light brown limestone; fiercely eff.	5	2030
Dark gray limestone, some chert.....	10	2040
Very fiercely eff. limestone with much brown chert, a little pyrite and some clay at 2040 ft.		
Water at 2300 ft. Filled hole 600 ft. before cased off. No record of the lower part of drilling.		
Total depth.....		2300 +

EATON COUNTY.

Charlotte. A well 2209 feet in depth was drilled at Charlotte many years ago by E. Shepard and F. W. Higby. The calcareous nature of the Coldwater shales is to be noted as this appears to be rather characteristic of the Coldwater in the western part of the State. The Berea horizon is represented by gritty red shales. This formation exists as a sandstone only on the eastern side of the Basin, being generally represented by red shales in the western half of the State. Brine was reported in the Dundee, but doubtless water was also struck in the Parma and the Marshall sandstones.

CHARLOTTE WELL.

E. Shepard and F. W. Higby. Driller's record and notes on samples examined by A. C. Lane.

Elevation 906 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Rock.....	72	72
Woodville or Parma:		
"Fine sandrock." Mainly quartz sand, with a very little calcite and larger bits of dark bluish gray shale; water.....	88	160
Saginaw Coal Measures. (Perhaps in part Grand Rapids):		
"Fine shale." Quite dark bluish, with black specks (fossiliferous?), very finely divided quartz, much clayey matter and but a trace of cal- cite.....	210	370
Grand Rapids Group:		
"Fine sand rock." A somewhat sandy, medium gray shale; no reac- tion for gypsum; a trace of calcareous matter. There are some frag- ments very fine grained, but quite gritty.....	200	570
Upper Marshall or Napoleon:		
"Soft sand." Fine grained; quite calcareous; greenish gray sandstone, showing under the lens distinctly the rounded grains of colorless quartz. One larger piece shows distinctly the grayish or greenish white sand- stone, with the rounded quartz sand and occasional specks of mica.....	110	680
Coldwater shale (Some of the top is probably Lower Marshall):		
"Shale and sand." Argillaceous limestone, with a little quartz and green earth; greenish gray.....	320	1000
Much like the preceding 320 ft.		
"Calcareous shale, eff. briskly....."	150	1150
"Soft sand?" Much of the matter greenish gray argillaceous, as in pre- vious samples, but there are also fragments of siderite or dolomite, often brownish. These may represent nodules of kidney iron ore.....	310	1460
"Sand and slate." Somewhat sandy limestone; contains some brown and white mica. (Richmondville?).....	40	1500
"Soft slate." Calcareous shale with traces of quartz.....	160	1660
Berea (?):		
"Hard sand." Gritty calcareous shale. In the whole preceding sec- tion there is no distinct break.....	20	1680
"Red rock." Calcareous red shale; gritty; ferruginous.....	20	1700
Antrim shale:		
"Shale." Black shale, with occasional harder reddish fragments, barely calcareous.....	200	1900
"Shale." Brownish black bituminous shale, non-calcareous; burns with an aromatic smoke.....	30	1930
Traverse (Hamilton) Formation:		
"Shale." Shows frequent pyrite; black bituminous and gray grains, slightly calcareous.....	20	1950
"Shale." Gray calcareous shale with bits of calcite from fossils.....	30	1980
"Shale and lime." Highly fossiliferous shale full of bits of brachiopods(?) and of black matter.....	5	1985
Dundee (Corniferous) limestone:		
"Top of limestone." Gray limestone, briskly eff.....	15	2000
"Limestone." Brine at 2050 ft.; eff. briskly, with a cherty residue and a little quartz. All these limestones down to 2121 ft. are yellowish or buff ferruginous with magnetite.....	50	2050
Brine:		
Sp. g. 1. 198.		
Salin .97°		
"Limestone." Eff. briskly.....	35	2085
"Limestone." Acid water in it. Eff. briskly; residue of cherty dolo- mite, quartz, magnetite and pyrite.....	15	2100
"Limestone." hard water under it. Eff. briskly; residue of chert, quartz, green grains, with iron rust, magnetite and pyrite.....	2	2102
"Limestone." like previous sample, residue larger.....	3	2105
"Limestone." damp, reacts faintly from sulphates (gypsum), like pre- vious sample.....	16	2121
"Limestone." Buff to gray, with little fragments of iron ore in thin seams (hematite; magnetic), but little quartz and no chert.....	29	2150
"Limestone." Buff to gray; slight residue of chert and quartz.....	59	2209
Driller's (?) record in quotation marks.		

Grand Ledge.—A comparatively shallow well was drilled at Grand Ledge a few years ago, but only a meagre record is available.

TABER WELL.

Record by W. D. Southworth.

Elevation about 860 ft. A. T.	Thick- ness, feet.	Depth, feet.
Coal Measures:		
Sandstone.....	75	75
Coal.....	2½	77½
Sandrock. Fresh water at 110 ft. in sandrock and large vein at 287 ft....	222½	300
Michigan Series:		
Chalk rock.....	3	303
Shale. Mineral water at 385 feet.....	209	512

Eaton Rapids. In 1910 and 1911, two wells were sunk for oil in Eaton county, one at Smithville near Eaton Rapids, and the other about one mile south of Delta on the J. Hitchcock farm. The Eaton Rapids well reached a depth of at least 2005 feet for samples from 1510 to 2005 feet were preserved for the Survey. The samples above 1510 feet were never received. The well appears to have reached the Berea horizon, but no marked signs of gas and oil were observed at any horizon, according to reports. The well was not finished owing to legal troubles or other difficulties.

EATON RAPIDS OIL WELL.

Loc.: Smithville, Hamlin township, Eaton county. A. E. Smith, owner, Jno. Flanagan and J. A. Gardner, drillers. Samples by A. E. Smith.

Elevation about 900? ft. A. T.	Thick- ness, feet.	Depth, feet.
Samples missing to.....		1510
Coldwater:		
Light gray shale.....	30	1540
Light gray shale, slightly gritty.....	30	1570
Light gray shale, non-calcareous.....	30	1600
Light gray shale.....	150	1750
Light gray shale, gritty.....	90	1840
Gray shale with red streaks.....	60	1900
Red and white shale (oxidized after exposure to air?).....	80	1980
Berea at about 1975 ft.?:		
Antrim (Sunbury?):		
Pyritic black shale.....	10	1990
Sandstone (Berea?) conglomeratic, chert, feldspar, epidote?, magnetite, green and white quartz, limonite fragment, dark sandstone, fragments of black shale, calcite.....	5	1995
Black shale and limestone.....	10	2005

Delta. The Delta well, about 2330 feet in depth, was started in 1911 and work was not finally abandoned until the fall of 1912. The location of the well was made by the use of an "instrument" but little or no trace of oil was found, although the drill apparently penetrated the Dundee about 30 feet.

The well appears to have been started without any knowledge con-

cerning the character, thickness and depth of the formations, or of the water and probable oil horizons; as a consequence, much time and money were wasted in casing off the numerous water bearing strata down to the Coldwater shales. According to reports, the casing was pulled and the hole reamed out 8 or 9 times before the last water horizon above the Coldwater was passed. The depth to the oil horizon appears to have been greatly underestimated, so that the drilling outfit brought in was inadequate for penetrating to the depth necessary to reach the Dundee oil horizon. Indeed, the drilling had to stop when supposedly within only a few feet of the coveted goal. Samples were taken and a log was kept by Mr. Ricker, owner of the well, but no record and only a partial set of samples reached the Survey. The following is the log compiled from verbal statements of one of the drillers and Mr. Ricker and from an examination of the partial set of samples.

DELTA WELL.

Loc.: One mile south of Delta on Carrier Creek, sec. 10, Delta township, Eaton county. E. Hitchcock farm.

Elevation about 830 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	40	40
No record. (Much white sandstone, some shale, with big flow of fresh water above 428 ft.).....		
Grand Rapids:		
Dolomitic sandstone similar to 875 ft. at.....		544
No record. (Much sandstone and some shale).....	196	740
Calcareous white sandstone.....	10	750
Dolomite and sandstone.....	10	760
Light gray shale, soft.....	5	765
Upper Marshall:		
Fine white sandstone.....	15	780
Much water (artesian) down to Coldwater.		
Fine grayish white dolomitic sandstone.....	50	830
Lower Marshall:		
Red sand and gray shale.....	5	835
Fine gray dolomitic sand.....	5	840
Very fine dolomitic sand.....	5	845
Very fine dolomitic sand, very sandy.....	10	855
Dolomitic gray limestone, slow eff. in cold HCl.....	10	865
White and very fine white sandy dolomite.....	25	890
Coldwater shale:		
Gray calcareous shale.....	10	900
Samples missing, probably blue and gray shales.....	300	1200
Gray shale, fossiliferous at.....		1200
Samples missing, probably blue shale.....	575	1775
Mineral water from sandstone lens in the Coldwater, 10-15 bbls. per day.		
Gray dolomite.....	2	1777
Gray shale.....	73	1850
Extremely fine grained gray sandstone (Berea?), ferruginous with fine black specks similar to Saginaw Berea. Richmondville?.....	45	1895
Light gray calcareous shale.....	5	1900
Argillaceous dolomitic limestone, cherty.....	5	1905
Berea?:		
Red shale, calcareous.....	5	1910
Antrim shale:		
Dark gray shale.....	5	1915
Black and very bituminous shale at.....		1950
Dundee limestone:		
Cherty shell at 2304 ft.: Buff or brown limestone, fiercely eff. Some chert, pyrite, and limonite fragments. (From pyrite?). Dundee very hard. According to Mr. Ricker the shell at 2304 ft. required 36 hours to penetrate. The artesian flow above 425 ft. was very strong and the water fresh, though there was a slight smell of "sulphur".....		2330

Comparing the top of the Antrim black shale in the Charlotte and Delta wells, the dip is about 16 feet per mile to the north which is comparable to the dip of 17 feet per mile northeast from Kalamazoo to Charlotte. The striking fact is, however, that the black shale in the Eaton Rapids and Delta wells are practically at the same level, indicating little or no dip directly northward from the first place, therefore a structural bench, or possibly an anticline may exist between Eaton Rapids and Delta. More reliable data, however, is necessary before a positive statement is warranted.

INGHAM COUNTY.

Lansing. There are several drillings at Lansing from 350 to 1400 feet deep. The Hoffman well 700 feet and the old Lansing Magnetic 1400 feet in depth flow, but the water in both wells comes from the upper strata. Dr. Lane suggests that the latter well may have reached the Berea, but this is hardly possible for the Berea in the Eaton Rapids and Delta wells appears to be fully 1900 feet or more below the surface. Unfortunately no record of the rock strata penetrated in the old Magnetic well was kept. The record of the well at the State Industrial School is given below.

INDUSTRIAL SCHOOL WELL.

Loc.: At the School in the eastern part of Lansing.

Elevation about 840 ft. A. T.	Thick- ness, feet.	Depth, feet.
Clay and gravel.....	36	36
Sand and gravel.....	5	41
Sandy hardpan.....	4	45
Lake sand and gravel.....	39	84
Clay, sand and gravel.....	16	100
Lake sand and gravel.....	1	101
Coal Measures:		
Soft sand rock.....	3	104
Hard fire clay.....	4	108
Soft white sand rock.....	13	121
Soft sandy fire clay.....	15	136
Hard sand rock.....	119	255
101 to 255 is sandstone. "first water"—Winchell.		
Hard fire clay alternating with beds of sand rock, variable in color from whitish to blue.....	64	319
Cherty lime.....	1	320
Gray lime.....	4	324
Sandy fire clay mixed with seams of hard rock.....	51	375
Soft sand rock.....	37	412
Hard gray limestone.....	2	414
Soft white sand rock.....	15	429
Blue limestone.....	1	430
White fire clay.....	1	431
Sand rock.....	4	435
Fire clay with iron pyrites.....	50	485
Soft sand rock.....	5	490
Blue limestone.....	16½	506½

Mason. The E. Strobe well at Mason is about 650 feet deep and flows a weak stream. The upper rocks down to 200 feet are mainly sandstone increasing in porosity with depth and yielding abundant water.

JACKSON COUNTY.

Jackson. At Jackson, three wells, respectively 2455, 2174, and 2100 feet in depth, have been drilled. The No. 1, or Worthington & Cooley Manufacturing Company well probably reached nearly to the bottom of the Monroe formation. An abundance of water was struck in the Marshall (including Parma?) with an "extra" flow at 218 feet, near the middle of the Coldwater, in the top of the Dundee, and at several lower horizons. According to the record, about 270 feet of "black shale" forms the base of the Coldwater, but only the last 28 feet is described as bituminous. The Berea is present, but it is very shaly. There is about 50 feet of blue sandstone at 660 feet in the Coldwater which, in Volume V, Dr. Lane correlated with the Marshall. The Antrim is characteristically black, the Traverse thin but typical with its calcareous shales or "soapstones," and the Dundee shows the exceptional thickness of over 250 feet.

JACKSON WELL.

Loc.: Worthington & Cooley Mfg. Co. R. M. Decker & Co., drillers. Record from driller's log and samples.

Elevation 928 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or Surface:		
Quicksand and clay.....	22	22
Saginaw Coal Measures:		
Shelly sandstone.....	14	36
Black shale.....	10	46
Fine gravel (conglomerate).....	5	51
Black shale (fireclay?).....	32	83
Limestone.....	5	88
Grand Rapids Group?.....		?
Marshall (Plus Parma at top?) sandstone:		
Mainly calcareous gray sandstone with minor amounts of argillaceous sandstone. Part of the bottom may be limestone or shale as shown in the other Jackson wells.....	285	373
Extra flow of water at 210 ft.		
Black shale.....	7	380
Blue sand.....	5	385
Dark shale and calcareous drab sandstone.....	30	415
Dark gray shale and blue sand (light gray to dark drab shale).....	15	430
Dark gray shale and sandstone.....	15	445
Coldwater shale:		
Dark shales slightly calcareous at some horizons.....	215	660
Blue sandstone slightly calcareous.....	50	710
One foot of brown limestone at 665 ft.		
Dark gray clay shale.....	420	1130
Sandstone at 725 ft.		
One foot of limestone at 770 ft.		
Water commenced to flow at 1050 (?) ft. after nearly ceasing just before this depth.		
"Black" shale.....	208	1338
Some show of limestone at 1255 ft.		
Dark drab shale with 10 per cent brownish red at 1338 ft.		
Reddish brown shale.....	34	1372
Bituminous black shale (called coal).....	3	1375
Dark gray and black (Sunbury) shale.....	25	1400
Berea Grit.		
Sandy shales.....	65	1465
Antrim Shale:		
Dark gray shale.....	10	1475
Bituminous black shale.....	135	1610
Very black shale at 1555 ft. with some smell of petroleum; also at 1570 feet.		
Blue shale.....	14	1624
Black shale.....	36	1660
Petroleum smell at 1655 ft.		
Brownish black calcareous shale.....	45	1705
Thin hard flinty shell at 1705 ft. Samples show bituminous black shale.		
Traverse (Hamilton) Formation:		
Dark gray calcareous shale.....	55	1760
Dundee (Corniferous) limestone:		
Limestone changeable in color; cherty or sandy. Brine at 1765 ft.	82	1842
Very hard white shell at 1842 ft.		
Sandy limestone; "could run only 2 feet before sharpening; bitter water".....	6	1848
Limestone calcareous and argillaceous; mainly gray in color, some yellow.....	19	1867
Calcareous blue shale.....	17	1884
Limestone gray, yellow or buff in color, often cherty or shaly.....	131	2015
Monroe Formation:		
Dolomite with anhydrite and gypsum with an abundance of marls of various colors. The marls are very salty, sometimes quite sandy and often with 10 to 20 per cent of gypsum or anhydrite.....	385	2400
Sandy dolomite.....	45	2445
Marls with chert, anhydrite with more or less salt and quite ferruginous; some gas.....	10	2455

The Woodworth well was drilled in the northern part of the city in 1883 and only a driller's (Fred Saeger) record is available.

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JACKSON NO. 2 WELL.

Loc.: Woodworth's farm, north side of city. Driller's (?) (Fred Saeger) record, 1883.

	Thick- ness, feet.	Depth, feet.
Surface:		
Clay.....	6	6
Gravel.....	14	20
Saginaw Formation:		
Brown limestone (Grand Rapids Group?).....	30	50
Fine clay.....	90	140
Marshall Formation:		
Sandrock.....	160	300
Coldwater shale:		
White shale.....	815	1115
Sandy shale, brackish. Brine.....	6	1121
White shale.....	289	1410
Berea?:		
Red shale.....	8	1418
Antrim shale:		
White shale.....	11	1429
Brown limestone.....	1	1430
Black shale.....	15	1445
White shale.....	52	1497
Sandy shale.....	15	1512
White shale.....	15	1527
Brown limestone.....	3	1530
Brown shale, contains gas.....	71	1601
Brown shale.....	99	1710
Black shale.....	20	1730
White lime.....	12	1742
Black shale.....	25	1767
Traverse Formation:		
White shale.....	40	1807
Sandy shale.....	10	1817
Dundee (Corniferous) limestone:		
Brown lime.....	228	2045
Monroe Formation:		
White shale (i. e. anhydrite—L.).....	9	2054
Sandrock.....	15	2069
White shale.....	10	2079
Sandrock.....	12	2091
White shale.....	15	2106
Gray lime.....	2	2108
White shale.....	15	2123
Porous sandstone, salt rock.....	5	2128
White shale.....	15	2143
Gas rock.....	20	2163
White shale.....	10	2173

The Jackson No. 3 well was drilled near Francis and Milwaukee streets and was begun in 1863. Only a very incomplete record is available.

JACKSON WELL NO. 3.

Loc.: Francis and Milwaukee Sts. Driller's record. 1863.

	Thick- ness, feet.	Depth, feet.
Surface:		
Drift.....	5	5
Saginaw Coal Measures:		
Sandstone.....	60	65
Fire clay. Pronounced first class by gas-retort men.....	23	88
Marshall:		
Sandstone.....	203	291
Coldwater:		
Limestone.....	97	388
Slate.....	340	728
Saline from 685 ft. on increasingly.		
Salt water at 1040 ft. 20 per cent salt.		
Oil in traces at 1395 ft.		
Argillaceous slate at 1443 ft.		
Reached 1800 ft. on February 12, 1864.		
Reached 2000 ft. on June 4th, 1864.		
Bottom 2100 ft.		

CALHOUN COUNTY.

Goguac Lake. The Marshall sandstone underlies the surface in Calhoun county throughout a belt extending from the northwest to the southeast. None of the wells for water at Albion, Marshall, and Battle Creek are over 500 feet in depth, as water is generally struck in abundance in the sandstone at shallow depths. A few of the test wells however, penetrate the Coldwater shale 200 or 300 feet. In the Goguac lake well near Battle Creek, traces of oil were found in these shales.

GOGUAC LAKE WELL NO. 6.

Loc.: At Goguac Lake near Battle Creek. Drilled in 1902 for Battle Creek Water Works by Slim Coleman. Size of pipe 8 inches. Record by W. F. Cooper.

Elevation 903 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Lake sand and cement gravel.....	15	15
Fine lake sand.....	55	70
Dark sand and gravel with strong taste and smell of "sulphur".....	10	80
Quicksand with some lake sand.....	118	198
Soft blue clay, with some coarse gravel with some streaks of light gray sand rock.....	10	208
Coldwater shale:		
Blue shale.....	198	407
At 287 ft. found indications of oil in dump from sand pump. Estimated one gill of oil to 10 gallons of dump.—Cooper.		
Hard gray sand rock.....	3	410
Soft blue shale.....	20	430

LIVINGSTON, SHIAWASSEE AND CLINTON COUNTIES.

Local Geology. A comparison of the wells from Genesee and from southeastern Saginaw county, southwest to Eaton and Barry counties

across the southeastern part of the Central Basin indicates that the strata in northwestern Livingston and southern Shiawassee counties are higher than to the northeast or southwest, contrary to what should be expected. Unfortunately, the wells in these two counties are too shallow to reach horizons which can be definitely recognized, or their records are of such doubtful character, that the evidence indicating the presence of an anticline is inconclusive.

On the eastern side of the Basin, the Berea sandstone appears to have been struck at 1545 feet at Blackmar (610 ft. A. T.), 1500 feet at Columbiaville, and 1200 feet at Flint (723 ft. A. T.) West of the meridian of Jackson the Berea is apparently absent, but its horizon is usually represented by red shales, generally very sandy. At Jackson this red horizon occurs at 1410 feet, at Eaton Rapids ($900 \pm$ ft. A. T.) 1980 or 1995 feet, at Charlotte (906 ft. A. T.), 1680 feet, at Assyria (917 ft. A. T.) 1400 feet, and at Delta ($830 \pm$ ft. A. T.) 1905 feet. The sandstone horizon at the bottom of the old mineral well at Lansing could not have penetrated this horizon at 1400 feet as shown by the Eaton Rapids and Delta wells.

Near Morrice close to the Looking Glass river (850 ft. A. T.) on sec. 25, T. 6 N., R. 2 E., C. W. Gale drilled a deep well in the 60's. The record obtained is one from memory, and it appears that the well was drilled to the depth of about 1135 feet and much black shale and also "blue clay" were struck. A strong brine was struck at the bottom which according to reports flowed and did not smell of sulphur. A little oil used to occur on the surface of the river.

Little dependence should be placed on such a record as drillers are careless in their observations and statements, and too often they pay little attention to the character of the horizons above the one which they desire to reach. The great amount of blue clay and black shale reported in the well, however, is similar to the Coldwater and the Antrim. It is also to be noted that in the Jackson No. 1 well, according to C. E. Wright, the upper part of the Coldwater is drab "slate" and the lower 270 feet including the Sunbury shale, "black slate," but in the other wells at Jackson, however, there are only white shales according to the drillers' records. The Durand and Howell wells and the Jason and Shumway well (1000 ft. A. T.) northwest of Fowlerville on the Grill farm, sec. 17, T. 4 N., R. 3 E., likewise show the same abundance of black or brown shales. According to Lane, the brown shales of the Jason and Shumway well may correspond to the Coldwater, the coarse brine bearing sandstone between 600 and 800 feet to the Berea, and the black shales beneath the latter to the Antrim. Lane argues that if this sandstone is the Marshall then there is an abnormal amount of black shale associated with it, for, as a rule,

black shales are rarely found in association with this formation, but are nearly always associated with the Berea.

According to the village clerk, in the municipal well for water at Perry, Shiawassee county, drilled in 1914, blue shale extends from about 200 to 600 feet with about 30 feet of water "gravel" (conglomerate?) below 250 feet. The well was continued to 725 feet where brine was encountered. The Perry well is only about 7 miles northwest of the Jason-Shumway well and the brine horizon at 725 feet may correspond to that at 600 feet in the latter since the elevation of the two wells is about the same and the rock strata dip to the northwest. The preponderance of "blue rock" in the Perry well tends to throw doubt on the reports of so much black shale in the Jason-Shumway well. Quite possibly dark shale has been reported as black shale by the drillers. The 270 feet of "black shale" above the Berea in the Jackson No. 1, however, is comparable in amount to that in the Shumway well above the coarse brine bearing sandstone supposed to be the Berea, this sandstone may be the Richmondville or a stray sandstone in the Coldwater above the true Berea horizon.

If this sandstone in the Morrice and the Jason-Shumway wells is the Berea, then there is a very pronounced arching of the strata in the vicinity of Fowlerville. (Fig. 2). If such is the case, it is difficult to explain the absence of the Marshall and a large part of the Upper Coldwater. Lane advances the idea that this uplift and arching preceded the deposition of the Coal Measures but not that of the Grand Rapids Series, in which case, the Grand Rapids Series, and locally the Marshall, and Upper Coldwater were either not deposited or were eroded away. This would bring the Parma sandstone directly above the Coldwater or above the Marshall. In the latter case, the Marshall and the Parma could not be distinguished, as they are very similar in appearance.

There is further evidence in support of Dr. Lane's hypothesis of a pre-Coal Measure uplift and folding. From the studies of Dr. Sherzer in southeastern Michigan, the formations, down to the Traverse at least, are about 200 feet higher at Ann Arbor than they are on either side at Adrian and Pontiac. This fold, which is nearly 70 miles in breadth apparently pitches northwest in the direction of Livingston county, and perhaps is directly related to the supposed fold in the latter county, which, if it exists, probably runs northwest from Fowlerville through Laingsburg or its vicinity.

It must be admitted that the evidence, while highly suggestive, is not sufficient to draw a positive conclusion. A carefully made drilling to the Dundee in northwestern Livingston county, or in southeastern Shiawassee county would doubtless prove whether or not there is a pronounced anticline as indicated by the evidence.

LIVINGSTON COUNTY.

Fowlerville. The Jason-Shumway well, northwest of Fowlerville, though full of strong pure brine and plugged, constantly leaked gas which came from the sandstone mentioned in the previous paragraphs. The abundance of black or brown shale is not unfavorable for the occurrence of oil and gas.

JASON-SHUMWAY WELL.

Loc.: Sec. 17, T. 4 N., R. 3 E., Grill Farm.

Elevation of well 900 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface to rock (8-in. drive pipe)	95	95
Slate (at 120 ft. oily at the house)	35	130
Shale (gas at 155 ft.)	63	193
Gray sand (dry well from 200-600 ft.)	25	218
Brown shale (gas at 380 and 600 ft.)	382	600
8-in. hole for 587 ft., cased at that depth with 5 7-8 in. casing.		
Coarse gritty sand with salt water (Beres?)	200	800
As analyzed, filled the well, and slowly oozed out in spite of a plug, with bubbles of fuel gas, and a temp. of 65%.		
Black shale	20	820
Brown shale	150	970

Fowlerville.—In the northwestern part of Livingston county about 4 miles southeast of Fowlerville, oil was struck apparently in dark sandstone lens in blue shale at the depth of only about 157 feet. The oil horizon is in the Coal Measures, which underlie the northwestern half of Livingston county. The well, if pumped, might have yielded half a barrel of oil per day.

FOWLERVILLE OIL WELL.

Loc.: Two miles south and 2 3-4 miles east of Fowlerville in N. E. $\frac{1}{4}$ of sec. 6, T. 3 N., R. 4 E. Henry White farm. 1903.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Clay	30	30
Sand	8	38
Gravel	2	40
Sand	6	46
Blue clay	28	74
Sand	30	104
Gravel	2	106
Sand and gravel	22	128
Coal Measures:		
Sandrock	8	136
Blue shale with oil and gas, the flow being estimated at about one-half barrel per day	30	166
Dark sandstone at 157 ft.		

SHIAWASSEE COUNTY.

Owosso. Four miles northeast of Owosso, C. W. Collyer in 1863, as it appears, drilled a well 1000 feet deep. The Marshall was struck at 556 feet, but, below 601 feet, white and blue shales with red horizons predominated. The Grand Rapids Group appears to be little represented, probably eroded or not deposited as it is absent farther east.

OWOSSO WELL.

Loc.: Four miles northeast of town. C. W. Collyer, 1863.

Elevation 745 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Gravel, sand, etc.	94	94
Jackson Coal Series:		
Gravel and clay.	6	100
Clay, mixed with sand and gravel.	26	126
Shale.	20	145
Coal.	4	150
Shale.	100	250
Parma sandstone:		
Sandrock.	47	297
Sandrock, very hard.	4	301
Sandrock.	103	404
Sandrock of white quartz pebbles; resembles split peas.	31	435
Sandstone.	38	473
Grand Rapids Series:		
Limerock (dissolves in acid).	3	476
Blue shale.	29	505
Blue shale.	28	533
Brown lime-rock.	3	536
Soapstone. Brine at 541 ft.	20	556
Upper Marshall:		
Sandstone.	45	601
Brine at 557, 572 and 601 ft.		
Coldwater and Lower Marshall:		
White shale and sand, brine at 616 and 633 ft.	115	716
Blue shale.	23	739
White shale (gray).	50	789
Blue shale.	31	820
Brown shale and white lime-rock.	9	829
Blue shale.	15	844
Blue limestone.	7	851
Red shale.	3	854
Blue shale.	32	886
Red shale.	3	889
Blue shale.	64	953
Red shale.	10	963
Blue shale.	37	1000

Durand. The rock strata in the Durand well are so variable in character, that it is hard to correlate them with the rock strata at Owosso. Lane thinks that, if the anticline mentioned on previous pages is present in Livingston county, the structure extends south-east to Durand, and the Marshall is not represented.

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DURAND WELL.

Record from blue print furnished by Grand Trunk R. R.

Elevation about 790 (?) A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface clays.....	12	12
Quicksand.....	7	19
Gravel.....	4	23
Hardpan.....	18	41
Gravel.....	2	43
Hardpan.....	19	62
Gravel.....	1	63
Hardpan.....	15	78
Blue clay.....	10	88
Hardpan.....	10	98
Gravel.....	2	100
Hardpan.....	9	109
Saginaw Coal Measures:		
Brown shale.....	65	174
Parma:		
8 in. casing to 176 ft..		
Water bearing gravel.....	4	178
If this is really under shale it must be a conglomerate.		
Hardpan and stones.....	60	238
Iron casing 208 ft.		
Grand Rapids (?) or Lower Marshall:		
6 in. casing to 267 ft. 89 ft. farther.		
Black shale.....	103	341
Well plugged at 332 ft.		
Blue shale.....	2	343
Black shale.....	12	355
Limestone.....	1	356
White shale.....	67	423
Green shale.....	10	433
White shale.....	54	487
Blue shale.....	20	507
Limestone.....	1	508
Blue shale.....	92	600
Limestone.....	5	605
White shale.....	14	619
Blue shale.....	24	643
Salt bearing sandstone.....	5	648
Well yields 4 gallons of brine per minute.		

CLINTON COUNTY.

St. Johns. Near the Water Works at St. Johns are three deep wells ranging from 574 to 780 feet in depth. The record of the No. 3, obtained as this report went to press, shows that the Marshall sandstone occurs at 700 feet below the surface.

ST. JOHNS WATERWORKS WELL.

Loc.: At plant.

Elevation about 765 + ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Clay with thin layers of quicksand..... (This indicates the depth of the moraine at St. Johns. There is a heavy water bed at 28 ft., but the supply is too near the surface to be considered safe.)	40	40
Coarse gravel.....	112	152
Saginaw Coal Measures:		
Red sandstone, bearing some water.....	20	172
Blue shale.....	202	374
Black shale with alternating hard and soft layers.....	1	375
White, water bearing sand rock (Parma?).....	150	525
Gray, water bearing sand rock.....	10	535
Michigan Series?		
Black shale.....	15	550
Blue shale.....	24	574

ST. JOHNS WATER WORKS WELL.

Loc.: At water and lighting plant. Record No. 2.

Elevation 753 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Blue clay	19	19
Pipe clay	12	31
Clay and hardpan	61	92
Stony and hardpan	19	111
Granite boulder	24	113
Soft clay	10	123
Gravel and hardpan	13	136
Hardpan	5	141
Coal Measures:		
Red sandrock	5	146
Sandrock	20	166
Gray sandrock	17	183
Yellow sandrock	17	200
To shale rock	14	214
Shale rock	3	217
Slate rock	26	243
Blue sandrock	21	264
Yellow sandrock	23	287
Yellow hard and lighter	51	338
Parma sandstone:		
Sandrock	6	344
Hard blue sandrock	44	388
Water rock	23	411
Blue sand, harder	45	456
Maxville or Bay Port:		
Slate	12	468
White sand	10	478
Water rock sand	17	495
Blue packed sand	22	517
White water rock	10	527
Blue sand	13	540
Michigan Series:		
Hard strata	10' 4"	541' 4"
Blue sand to white	18'	559' 4"
	3'	562' 4"
Hard blue sandrock	27'	589' 4"
Blue shale and sandrock (Very hard)	19'	608' 4"

WATERWORKS WELL NO. 3.

Loc.: Three hundred ft. north of Electric Light and Water Works, St. Johns; 10 inch well 301 ft. in depth, drilled in 1908; deepened in 1914 to 780 ft.; 6 inch hole. A. R. Purcell, Jackson, contractor; Chance Emley, driller. Record of 10 inch hole from records of Water Works Dept., remainder of record by R. A. Smith from samples and information furnished by Archie Bishop, Supt. Electric Light and Water Works.

Elevation 753 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Clay.....	10	10
Clay and gravel.....	20	30
Water sand.....	20	50
Fine sand and clay.....	20	70
Fine sand and blue clay.....	10	80
Blue clay.....	10	90
Clay and sand.....	22	112
Coarse water gravel.....	31	143
Red clay.....	8	151
Saginaw Coal Measures:		
Red sand rock.....	6	157
White sand rock.....	4	161
Soapstone (probably "fire clay" or calcareous shale).....	10	171
Blue shale.....	3	174
Red sandstone.....	9	183
White sandstone.....	5	188
Red sandstone.....	12	200
Blue shale.....	15	215
White sandstone.....	12	227
Soapstone.....	10	237
Red sand rock.....	10	247
White sand rock.....	8	255
Blue shale.....	10	265
Soapstone; end of 10 inch hole.....	36	301
Parma sandstone:		
Sandstone (Sandstone struck just below the bottom of the 10 inch hole, as reported by A. Bishop, Supt.).....	24	325
Fine white sandstone.....	100	425
White sandstone; coarse and pyritic; water.....	25	450
Maxville, or Bay Port limestone. Upper Grand Rapids:		
Gray limestone; vig. eff. Sample marked 150 to 520 and next sample 500 to 540.....	70 or 50	520 or 500
Grayish white sandstone, pyritic.....	20 or 40	540
Michigan Series or Lower Grand Rapids:		
Gray limestone with much sandstone; the latter apparently from the sandstone directly above.....	10	550
Snow white gypsum and some shale.....	30	580
Dark gray shale and white gypsum.....	120	700
Napoleon or Upper Marshall:		
White sandstone and strong brine.....	60	760
Gray sandstone and shale.....	20	780
Well bottomed in white sandstone at 780 feet. Water rises to within 34 feet of surface. Can lower the head but six feet.		

CHAPTER VII.

THE SOUTHWESTERN DISTRICT.

A large number of deep wells have been drilled for oil and water at various places in the southwestern part of the State as at Kalamazoo, Assyria, Dowagiac, Berrien Springs, Bridgman, Benton Harbor, Niles, White Pigeon, Constantine, and Allegan.

ALLEGAN COUNTY.

Though oil and gas were struck in many of the wells, only at Allegan has oil been found in possibly commercial quantities. Nearly a dozen wells 1300-1400 feet in depth have been drilled in and about the city in the last twenty or twenty-five years.

Allegan. About fifteen years ago the Allegan Gas, Oil & Mining Company drilled a number of wells at Allegan. According to Mr. J. G. Ellinger, president of the Company, their No. 1 well, which was located on the river flats near the Pere Marquette depot produced about 5 barrels per day natural, and this was not appreciably increased by shooting. The well was 1275 feet in depth, oil occurring in the sandy shales at 1245 feet and in a sandy limestone at the top of the Dundee at 1256 feet. For six weeks their No. 2 yielded about 3 barrels of oil per day of 24 hours and nearly enough gas to fire the boiler.

The sand was struck at 1328 feet practically at the same level as in the No. 1, as shown on the contour map (fig. 13). Both of these wells were abandoned as not being worth operating. The No. 3 (?) well was absolutely dry although the "sand," according to the drillers, looked very promising. This well, 1411 feet deep, was located on the higher ground in the eastern part of the city.

In 1912, the Northern Oil and Gas Company drilled two wells, the first on "high ground" near the southwest corner of the N. E. $\frac{1}{4}$ of section 32, Allegan township, and the second in section 28 on the river flats, 1800 feet north of the No. 1 well of the Allegan Gas, Oil & Mining Company. The No. 1 well was drilled to the depth of 1387 feet, the Dundee limestone, the "oil sand," being struck at 1318 feet, but very little oil was found even after shooting. There is an upper thin "sand" separated from a lower but much thicker one. In this well, the surface deposits were found to be exceptionally thick, rock being struck at 355 feet. Great quantities of water and hard "lime

shells," probably chert beds and siderite nodules, were encountered. The cherty "lime" just beneath the drift is about 75 feet thick and, near its base, it yielded a heavy flow of water upon which the bailer "running at top speed" could make no impression. It took several months to complete the well.

In the No. 2 well, 1340 feet in depth, the surface deposits were found to be only 87 feet deep, and little or no water was struck in the bed rock except in the lower part of the Dundee below the oil horizon. No casing outside of the drive pipe would have been needed. Owing to the soft character of the rocks and the absence of water troubles the well was completed in 13 days.

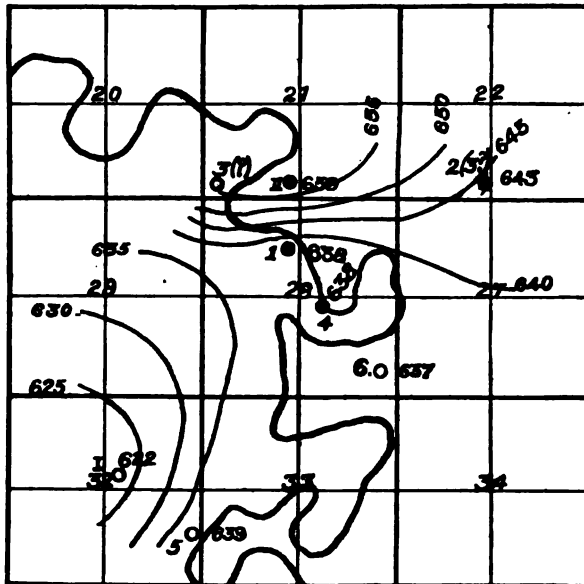


Figure. 13. Contour map showing the depth of the Dundee limestone below sea level in the vicinity of Allegan and the location of borings.
Roman numerals refer to the wells of the Northern Oil and Gas Company; Arabic to the older explorations.

Oil was struck at 1287 feet apparently in commercial quantity. The two oil "sands" separated by a few feet of gritty limestone consist of light buff to gray limestones of the Dundee. The well was shot December 6, 1912, with 120 quarts of nitro-glycerine, 60 quarts in each sand. Upon pumping, the well yielded about two barrels of oil per day and a little water.

The oil is dark reddish brown, smells of "sulphur" and tested about 36° Baume according to Mr. Mercer, president of the company. Little or no gas accompanied the oil.

Three of the wells drilled in Allegan yielded from 2 to 5 barrels of oil per well. If a group of such wells were drilled and operated from a central pumping plant as at Port Huron and in Ontario, probably, under the present high prices of oil, a fair return could be obtained upon the investment. As the oil horizons are twice as deep at Port Huron, the cost of drilling and operating the wells would be much greater.

Character of the Formations and Local Structures. All of the drillings show consistently that the blue-gray shales of the Coldwater, with here and there a red horizon, predominate down to about 1150 feet where the black shales of the Antrim begin. The Antrim is composed of gray shales in the upper portion and dark or black shales near the base. This formation is very thick but the Traverse is thin, the former being probably over 400 feet in thickness. The Dundee appears to be a cherty or sandy limestone very changeable in color with a shaly phase just below the top.

Through the kindness of Mr. C. F. Mercer, president of the Northern Oil & Gas Co., and Mr. Perry Fox, driller, the locations and altitudes of several of the former drillings were furnished together with all of the information available concerning the depth of the Dundee. In platting the wells according to sea level base, it is observed that there are irregularities in the general dip, and the most prominent structure is the apparent terrace or structural bench in sections 27 and 28 with the abrupt northward dip into the southern part of sections 21 and 22, Allegan township. The highest elevation of the Dundee occurs in the No. 2 well in section 32, yet this well yielded little oil or gas. The oil was found on the lower part of the terrace and on the steeper slopes to the north. It must be said, however, that some of the data may not be accurate. According to Mr. Mercer the Allegan Oil, Gas and Mining Co. well, Plate VI, Volume V, is located on the Kalamazoo river flats near the Pere Marquette depot, therefore could not have the altitude of 708 feet as given in Volume V. Owing to the doubtful location and elevation of some of these wells too much stress should not be placed on the structures as indicated by the records.

The following are the records of one of the older drillings and of the two wells drilled by the Northern Oil & Gas Co. The logs of the latter were made partly from memory and partly from notes by Mr. C. F. Mercer, president of the company, and Perry Fox, driller. The thickness of the various strata of rock are approximations. The depth to the Dundee, however, is accurate as it was carefully determined by steel tape measurements.

ALLEGAN GAS, OIL & MINING COMPANY WELL.

Loc.: In Allegan on bluffs above river flats? (near P. M. depot?). J. E. Ellinger, President.
Record by driller. Notes on samples by Lane.

Elevation 708? ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Sand and clay	120	120
Gravel and flowing water at 120 ft.		
Unreported	135	255
Slate and sandstone at 255 ft.; end of drive pipe. Sample impure gray banded sandstone at 255 ft.		
Coldwater shale:		
Sandstone. Brine at 292 ft. cased with 3 5-8 in pipe to 331 ft. Sample 260 pyritiferous bituminous coal, 275 siderite, 295 pyrite nodules and bluish shale, 331 brownish drab siderite, full of grains of calcite and pyrite with traces of fossils.	76	331
Blue shale.	249	580
Sample greenish bluish non-fossiliferous shales.		
Red rock.	15	595
Sample red and green mixed shale, calcareous red shale, residue of red clay, very little grit.		
Blue shale.	15	610
Sample red freely eff. shale.		
Red rock (Berea?).	5	615
Sample no eff. but burns from green to red with HCl.		
Antrim shale:		
Gray shale, fine drilling (in part Coldwater?). Sample no eff., greenish and bluish gray shales.	375	990
Black shale.	105	1095
Sample burns on heating—bituminous shale.		
Traverse (Hamilton) Formation:		
Hard rock, salt water between 1120 and 1200 ft.	80	1175
Sample siderite. This may be merely a large nodule.		
Black rock or slate.	20	1195
Sample bituminous black shale.		
Lime rock (top of Traverse?).	10	1205
Sample mixture of dolomite and black shale.		
Blue shale. Oil at 1245, crust very hard, turned drill.	55	1260
Sample greenish or bluish gray shale, slowly eff.		
Dundee (Corniferous) limestone:		
Sandy limestone, oil at 1264.	15	1275
Light yellow limestone rapidly eff., containing white chert and fragments of dark gray pyritiferous seams, also brachiopod fragments? Either Leptocella acutiplicata or Spirifer gregaria.	123	1400

NORTHERN OIL & GAS COMPANY WELL NO. 1.

Loc.: S. E. cor. N. E. $\frac{1}{4}$, sec. 32, Allegan Twp., H. F. Thomas farm. C. F. Mercer, president. Perry Fox, driller. Drilled in 1912.

Elevation 696 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand	320	320
Blue clay, sticky	20	340
Gravel, water	15	355
Coldwater shale:		
Flinty lime	10	365
End of drive pipe at 365 ft.		
Slate streaked in color	10	375
Black gritty lime or sand	15	390
Big flow of fresh water.		
Blue slate, no grit, soft	260	650
Cased 450 ft., 8 $\frac{1}{2}$ " casing.		
Red slate, hard	10	660
Little salt water under red slate. (Berea?).		
Blue shale, clean drilling, in part. Antrim?	500	1160
Berea? absent?		
Antrim shale:		
Light brown shale, changing to darker. Part of the shales grouped with the Coldwater are doubtless Antrim	110	1270
Traverse (Hamilton) Formation:		
Light blue shale, hard	10	1280
Gray lime, hard	3	1283
Blue slate	25	1318
Dundee (Corniferous) limestone:		
Light bluff lime. Oil	1	1319
Changed color most every screw.		
Total depth	68	1387
About water enough to drill with. Not accurate as to changes. Depth to top of Dundee measured by steel line.		

NORTHERN OIL & GAS COMPANY WELL NO. 2.

Loc.: S. E. cor. of S. W. $\frac{1}{4}$, Sec. 21, Allegan Twp. 1800 ft. north of old No. 1 (near P. M. depot) of Allegan Gas, Oil & Mining Co. and on river flats. Drilled in 1913. Record reported by Perry Fox, driller, and C. F. Mercer, president. Record from memory and rough notes. Top of Dundee accurate; measured by steel tape.

Elevation of well about 628 feet A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Ten in. drive pipe through drift	87	87
Coldwater:		
Soft blue clay or slate	200	287
Lime hard, black and dry	20	307
Lime shell	70	377
Slate, blue, soft	248	625
Yellow colored slate	5	630
Blue slate and red rock	10	640
Blue shale, hard (Largely Antrim)	510	1150
Berea absent?		
Antrim shale:		
Brown shale with streaks of black lime	70	1220
Part of shales above doubtless Antrim.		
Traverse (Hamilton) Formation:		
White or blue shale	15	1235
White lime shells	10	1245
Slate blue, hard	42	1287
Dundee (Corniferous) limestone:		
Lime called Dundee changeable, no grit	24	1311
Oil at 1287-1290 ft.		
Gritty lime	5	1316
Looked good for oil	10	1326
About 1 bbl. water an hour 1290-1295 ft.		
Total depth		1340
Pumped at an average of 2 bbl. oil per 24 hours.		
Shot with 120 quarts of nitroglycerine, 60 qts. above and 60 qts. below gritty lime.		

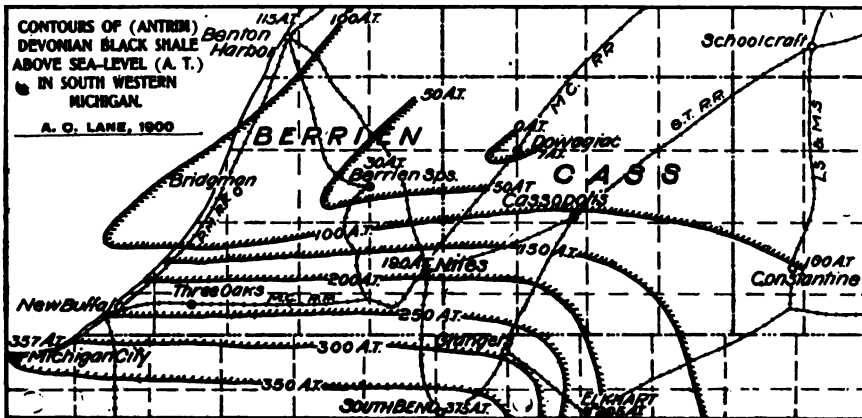


Figure 14. Contour map showing the indicated anticline east of Niles and the elevation above sea level of the base of the Antrim black shale in southwestern Michigan.

BERRIEN, CASS, ST. JOSEPH AND KALAMAZOO COUNTIES.

Local structures. From a comparison of the records of the wells in Berrien, Cass, and St. Joseph counties, and in western Indiana, it appears that in Berrien county a well defined trough or syncline extends northeast in the vicinity of Bridgman, Berrien Springs, and Dowagiac, and a less well defined anticline northeast from near South Bend and Grangers in Indiana into Cass county 10 or 12 miles east of Niles. At Benton Harbor the base of the Antrim black shale is about 115 feet A. T., at Berrien Springs 30 feet A. T., at Niles 190 feet A. T., at Dowagiac 0 feet A. T., at White Pigeon 227 feet A. T., and at Constantine 137 feet A. T. From this data it will be observed that from Benton Harbor to Berrien Springs there is a drop to the southeast of 85 feet in about 15 miles, and a rise of 160 feet from the latter place to Niles, a distance of 12 miles. The southern limb of this trough or syncline is much steeper than the northern. Southward the rise is pronounced from Berrien Springs to South Bend where the Antrim is nearly 350 feet higher, but south of South Bend the strata descends again, giving rise to the anticline (Fig. 14) mentioned above.

The territory in the vicinity of the Berrien Springs syncline may be classed as unfavorable for the occurrence of oil and gas, while the region from South Bend and Grangers, Indiana, northeast into Cass county may be worthy of exploration. This anticline seems to be related to the Kankakee uplift and therefore may have a much greater northeastward extension toward Jackson than indicated by present drillings.

Oil horizons. The Dundee oil horizon is comparatively shallow in

the vicinity of the anticline, probably being nowhere more than 1000 feet below the surface. At Niles, 10 or 12 miles west of the axis of the anticline, it is only 580 feet below surface.

The next probable oil horizon beneath the Dundee, excepting perhaps the Niagara, is the Trenton limestone, which is not only deeply buried, but wholly unknown. It is in this part of the State that drillers from Ohio have confused the Traverse or Dundee limestone with the Trenton. In the southwestern part of the State the drift is underlain by the blue shales of the Coldwater and the Antrim black shales. After penetrating these shales and striking a limestone beneath some black or brown shale, drillers are deceived and believe that they have struck the Trenton. The black shale is the Antrim, and the limestone that of the Traverse or Dundee. It is doubtful that the Trenton has been penetrated in southwestern Michigan.

CASS COUNTY.

Dowagiac. The only boring which may have reached the Trenton is the Dowagiac well, which is known to be 1760 feet deep, and which apparently penetrated the Lorraine shales.

DOWAGIAC WELL.

Loc.: Round Oak Gas & Fuel Co., Dowagiac. Drilled 1887 by Wm. M. Farr. Record by C. E. Wright from driller's notes and from samples.

	Thick- ness, feet.	Depth, feet.
Pleistocene or glacial drift:		
Fine and coarse sand	34	34
Gravel	4	38
Blue clay	18	56
Sand and some gravel	49	103
Blue clay	8	111
Coarse gravel	4	115
Blue clay, very tough	48	159
Coarse and fine sand and gravel	41	200
Coldwater shale:		
Blue argillaceous shale, slow eff.	82	282
Red argillaceous shale (Land surface belonging to the Antrim?—Lane)	12	294
Antrim shale:		
Argillaceous shale, light blue with streaks of hard blue sandstone. Slow eff. 90% residue	49	343
Argillaceous limestone, very hard	5	348
Argillaceous shale, slow eff. 95% residue	177	525
Sandy shale; dark bluish drab, hard and soft; slow eff. 90% residue	50	575
Argillaceous shale, dark drab and brown, quite soft; slow eff. 95% residue of clay	65	640 —
Argillaceous shale; dark brown, hard and soft; slow eff. 90% residue of clay	10	650
Argillaceous shale, dark brown, medium hard	35	685
Brown argillaceous shale, burning with aromatic smell	90	765
Traverse (Hamilton) Formation:		
Dark drab argillaceous limestone; brisk eff. 10-15% residue of clay	40	805
Dark drab coarse grained limestone; brisk eff. 2% angular grains of silica	68	873 +
Dundee (Corniferous) limestone:		
Light gray fine grained (coarse at 950 ft.) limestone; brisk eff. 4-5% angular grains of quartz and silica, 1% at 920 ft.	78	950
Dark drab fine grained limestone; brisk eff. 4%-5% of brown residue of silica and carbon	25	975
Light drab fine grained limestone; brisk eff. 5% of dark brown residue of silica and carbon	5	980
Brownish drab limestone; brisk eff. 5% siliceous residue	10	990
Monroe Formation:		
Dark gray and drab dolomite 25 to 30% residue of gypsum, anhydrite and silica	30	1020
Drab dolomite, fine grained; brisk eff. 10% residue of gypsum, anhydrite and silica	18	1038
Drab dolomite, fine grained; brisk eff. 12 to 25% residue of gypsum, anhydrite and silica	47	1085
Light gray dolomite, fine grained; brisk eff. 12% residue of gypsum, anhydrite and cherty silica at 1080 ft.		
Light gray sandy limestone (Sylvania?) 4 to 12% rounded grains of glassy sand, quartz and flint	15	1100
Niagara; Guelph and Lockport:		
Light gray limestone, dolomitic in part; 1 to 7% of chert, quartz, anhydrite, pyroxene	175	1275
Light gray argillaceous limestone 15 to 30% clay	45	1320
Gray limestone, dolomitic in part; brisk eff. 1 to 2% of rounded glassy grains of sand and angular ones of chert	120	1440
Creamy gray fine grained marley limestone; very brisk eff. 8% of silica and clay	40	1480
Creamy gray fine grained limestone, dolomitic in part	60	1540
Grayish white to gray fine grained limestone, brisk eff. 2 to 5% rounded grains of glassy sand and angular ones of flint, anhydrite, and clay	70	1610
Gray dolomitic fine grained limestone; brisk eff. 5% of silica and clay	35	1645
Creamy white marly limestone; 1 to 8% of rounded grains of sand, clay and anhydrite	35	1680
Rochester:		
Bluish drab clay shale; brisk eff. 95% clay	20	1700
Dark drab argillaceous limestone (Clinton?)	20	1720
Lorraine and Utica:		
Blue black calcareous argillaceous shale; slow eff. 95% clay	8	1728
Carbonaceous limestone brownish red to yellowish gray; brisk eff. 10 to 20% rounded glassy grains of sand, white chert and anthracite	32	1760

BERRIEN COUNTY.

Niles. At Niles, at least six wells have been drilled for oil and gas or water. One from 500 to 700 feet deep, drilled in 1865 close to the bridge, yielded some gas. Another, drilled about 1885 on Second street 20 rods from the railroad, yielded a large flow of water for some time after the drilling was completed. One of the drillers, also reported striking oil, claiming that, owing to outside influence, he had concealed the fact from the public. A third well was drilled about the same time near the C. C. & St. L. R. R. to about 1100 feet. No. 4 was located about one or two miles south of the city on a river terrace. A strong brine which rose nearly to the surface was struck at 546 feet and another in limestone, probably the Monroe, at about 850 feet. These were cased off, but fresh water was struck below 880 feet (Niagara?) and this rose as high as the first. Trenton rock was reported at 1000 feet, but the top of this formation must be several hundred feet deeper. Some gas was constantly given off, making the water "milky" or foamy. The well was abandoned apparently at 1438 feet, but it is claimed that the well was drilled to 1600 feet. Though this well is higher than those in the city, corresponding strata appeared to be struck at the same depth but this is what should be expected as the general dip of the strata should be northeasterly. The No. 5 (Vol. V) well, drilled in 1899, was located across the river 200 feet from No. 4 and only two or three feet above the water. It was about 518 feet deep, and yielded brine at 504 feet. By the use of a packer, the water was shut off and some gas was obtained. In 1903, a sixth well 592 feet deep was drilled by the Niles Oil & Gas Company about a mile west of Niles on the old Baumann farm. A little oil with brine was struck in the Dundee at the bottom of the well.

Nearly all of the oil and gas in the above wells apparently came from the Dundee or "bastard" Trenton which also yielded an abundance of brine some distance below the top and especially in its lower portion. In the No. 3 and No. 4, a little oil was struck in the top of the Niagara. A good log of the No. 6, or Niles Oil & Gas Company well was kept by Mr. F. W. Cook of the Niles Daily Star and a copy furnished the Survey. The log below shows the general character of the rocks down to the Dundee. This record tends to substantiate the general correctness of the hearsay records of the earlier wells.

NILES OIL & GAS COMPANY.

(Niles Well No. 6.)

Elevation 660 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Yellow impure sand (all the samples of the superficial deposits down to 265 ft. are more or less calcareous).....	91	91
Fine gravel (Torpedo sand) with water.....	12	103
Till (or boulder clay, sand and gravel mixed).....	79	182
Till.....	19	201
Clayey till.....	6	207
Clay, grit free, calcareous brown.....	10	217
Coarse sand.....	48	265
Antrim shale:		
Black shale, bituminous, very slightly calcareous (not so black as below).....	20	285
Black shale, bituminous.....	136	421
Traverse (Hamilton) Formation:		
Blue calcareous shale.....	141	562
Light colored limestone (nearly pure CaCo ₃).....	18	580
Dundee (Corniferous) limestone:		
Slightly darker, and more magnesia? (with oil and salt water).....	12	592 +

Berrien Springs. About 1900 a well 700 feet in depth (650+ ft. A. T.) was drilled at Berrien Springs about 60 rods north of St. Joseph river. The Hon. Roscoe D. Dix furnished an accurate record of the well as given below. As noted previously, the base of the Antrim black shale is respectively 160 feet lower than at Niles to the south-east and 85 feet lower than at Benton Harbor to the northwest, therefore Berrien Springs is near the bottom of the syncline. No oil was reported, but signs of brine were observed in the base of the Dundee, when drilling ceased.

BERRIEN SPRINGS WELL.

Elevation 650 + ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Gravel.....	40	40
Blue clay.....	70	110
Antrim:		
Soapstone.....	440	550
Reached 550 noon June 5. Compare Benton Harbor at 280 ft. Niles at 415 ft.		
Black shale with pyrite, bituminous.....	70	620
Compare Benton Harbor at 475 ft., Niles at 460 ft. Dowagiac at 675 ft.		
Traverse:		
Limerock with indications of salt water at bottom.....	80	700
Stopped at 670 ft., June 15. Compare Dowagiac at 874 ft.		

Some distance north of Berrien Springs a well was drilled to the depth of 1260 to 1300 feet, but no record was obtained. A good record would be valuable in showing whether or not there is a sudden northward rise of the strata. In 1903, the Umholtz Oil Company bored a well 620 to 625 feet in depth on the Umholtz farm about 8

miles north of Niles and 4 miles from Buchanan. Some oil and gas was struck at 618 feet just beneath black shale.

From a comparison of the wells in this part of the State, the Berea horizon shows considerable irregularity in character. This horizon appears to be nearly as reliable in yielding signs of gas in Michigan as the Dundee of oil. It is possible that gas in commercial amounts might be struck in this formation in the vicinity of favorable structures.

Bridgman. Some thirty years ago an oil well was drilled at Bridgman in Berrien county. A pocket of gas was struck which burned for some time. In 1904, a second well was drilled by the Bridgman Oil & Gas Company about 40 rods south of the depot. No record was kept of the drillings, but one of the workmen gave from memory the record below.

BRIDGMAN OIL AND GAS CO.'S WELL.

Loc.: Forty rods south of depot, on ground about 3 ft. lower than railroad track, e. l., 636 ft. A. T.—May, 1904.

Elevation about 636 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	3	3
Clay, sticky.....	100	103
Sand, fresh water.....	5	108
Clay, blue.....	50	158
Sand, some fresh water.....	5	153
Clay, blue.....	40	203
Sand, fresh water.....	20	223
Gravel, cement.....	5	228
Clay, blue, waxy.....	30	258
Coldwater shale:		
Clay (really shale), big break.....	50	308
Antrim shale:		
Brown shale, gas near top, seum on water after striking gas.....	200	508
Dundee (Corniferous) limestone:		
So called Trenton, "bastard".....	5	513
Samples 520 to 700, limestone with echinoderm fragments, quick eff.		
Salt sand.....	25	538
Brown sand, salt water rising nearly to the top.....	25	563
Trenton, porous, drilled nice.....	200	763
Salt water at bottom of this 200 ft., with traces of gas above.		
Monroe Formation:		
Sample at 768 a gypsiferous dolomite. Water stands 600 ft. deep in the well.....	5	768

Benton Harbor. At Benton Harbor a well was drilled for oil and gas by the Benton Harbor Natural Gas and Oil Co., but little or no signs of either were found.

BENTON HARBOR NATURAL GAS AND OIL CO.

Record by C. E Wright from samples. Samples from Fred Jordan.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Undifferentiated.....	130	130
Antrim shale:		
Bluish gray argillaceous shale.....	5	135
Red shale.....	15	150
Chocolate brown shale, eff. in cold Hcl; 70 per cent residue. Under microscope, fine fringy argillaceous mass and small granules; does not depolarize the light.		
Light blue shale; quite hard; eff. slightly; large residue, finely granular, apparently isotropic.....	20	170
Blue shale or "slate"; no sample.....	110	280
Black shale or "slate".....	195	475
Traverse (Hamilton) Formation:		
Argillaceous limestone; dark bluish drab; contains iron pyrites; brisk eff. 50 per cent residue of a fringy clay mass.....	165	640
Calcareous argillaceous shale; dark drab; medium hard; brisk eff.; 70 per cent residue of clay.....	25	665
Dundee (Corniferous) limestone:		
Arenaceous limestone; dark drab; brisk eff.; 20 per cent residue of rounded glassy grains of sand.....	35	700
Limestone, grayish white mixed with dark drab; brisk eff.; 10 per cent residue, mainly isotropic.....	11	711
Porous limestone; light gray; brisk eff.; 2 per cent residue of a finely granular mass.....	9	720
Grayish limestone; brisk eff. in cold acid, 10 per cent residue of round glassy grains of sand (and bits of green shale; no anhydrite).....	5	725
Similar?.....	10	735
Similar?.....	5	741
Dark drab to light drab limestone; brisk eff.; 5 to 10 per cent residue of rounded grains of sand.....	9	750
Water with strong brine at 750 ft.		
Similar?.....	5	755
Similar?.....	9	764
Light gray limestone; brisk eff.; 2 to 8 per cent residue of rounded glassy grains of sand.....	14	778
Brisk eff.....	10	788
Monroe (and Niagara?) Formation:		
Limestone; drab; brisk eff.; 20 per cent residue of sand and gypsum.....	27	815
Marly gypsum; very light gray; 80 per cent residue of anhydrite and a few grains of silica.....	17	832
Dolomitic limestone; drab; resembles sand; slight eff. in cold acid; 10 per cent residue of rounded glassy grains of sand, anhydrite and gypsum.....	108	940
Dolomite; slow eff. in cold acid; 3 to 20 per cent residue of grains of grayish sand.....	305	1205

In 1904, the Salzman Mineral Bath Co. drilled a well at Benton Harbor near the corner of 5th and Park Streets.

SALZMAN MINERAL BATH CO. WELL.

(U. S. Geological Survey Well No. 183.)

Loc.: Cor. 5th and Park Sts., Benton Harbor. Drilled in 1904.

Elevation 600 (?) ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Fine grained, light.	130	130
A sand, fine grained, and considerable variety in the grains, showing it must be a glacial sand.	5	135
Antrim shale:		
A light bluish shale.	215	400
Light, rather gritty silicious shale. I suspect that this is from the top of the strata.	180	580
Black shale. This is a typical Antrim or Ohio shale. If we may believe samples 4 and 5 the amount that is black is not as much as usual.	60	640
Traverse (Hamilton) Formation:		
Dark, with crinoidal limestone mixed; may represent the Traverse.	43	683
Record missing, probably limestone passing into shale 683-690 ft.		
Largely clay; perhaps the lower part of the Traverse.	60	750

ST. JOSEPH COUNTY.

White Pigeon. In 1903, the White Pigeon Oil & Shale Gas Co. drilled an 800 foot well near the northwest corner of the N. E. $\frac{1}{4}$ of sec. 22, T. 8 S., R. 12 W. The oil "sand" at 756 feet is a yellowish, cherty, fiercely effervescent limestone 75 feet below the top of the Dundee. At about 710 feet water was encountered which rose 400 feet. The well was shot "wet," i. e. without casing off the brine, at about 763 feet but without effect.

WHITE PIGEON WELL.

Loc.: Near the N. W. cor. of the N. E. $\frac{1}{4}$ of sec. 22, T. 8 S., R. 12 W. Record by A. C. Lane, from driller's log and from samples.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Quicksand, fine silt.....	120	120
Gravel, $\frac{1}{2}$ inch pebbles (limestone, chert quartzites, dark traps).....	20	140
130 ft. of 10 in. casing shutting off fresh water.		
Clay, blue calcareous.....	42	182
Compare surface to 93 or 136 ft. in the Constantine wells.		
Coldwater shale:		
Shale, blue non-calcareous.....	31	213
Quicksand.....	28	241
Calcareous and from the varied character of its grains, evidently a glacial sand, which must come in from some vertical fissure traversed by the drill, and yet is peculiar as being in very nearly the horizon of the Berea grit which yielded a strong brine and gas from 283 to 383 ft. in one of the Constantine wells, while in the other it seems to have been represented by 15 ft. of red shale, from 286 to 301 ft., while in this well it is not to be recognized at all. This variety in record is probably due to an unconformity at the base of the Carboniferous, and the red shale which appears in various records in this corner of the State may be due to the weathering and oxidation of black and green shales beneath an old land surface.		
Shale, dark blue, probably in part Antrim, belonging with the next division.....	224	465
Antrim shale:		
Black shale.....	108	573
This apparently corresponds to the base of the dark shales at Elkhart between 375 and 350 ft. down, and in the first Constantine well record the red calcareous shale immediately underlying is counted in, and 211 ft. of shales given between 492 and 703 ft. Corresponding horizons are found about 82 ft. deeper at Constantine.		
Traverse (Hamilton) Formation:		
Red calcareous shale.....	32	605
Very calcareous, gritty with a few large grains of sand and some crinoid buttons.		
Soft blue limestone.....	78	683
This formation was apparently not separated off in the Constantine records, but its base and top of the Dundee is probably nearly marked by the brine and sulphuretted hydrogen which occur at 790 ft. and correspond to the horizon of the "salt sand" from 696-711 ft. here. The red, gritty shale at the top may also mark a time between the Traverse and Antrim as here developed, when there was a land surface here. The paleontologist Schuchert assumes that there was a neck of land here at about such a time, and the more recent Niles and Dowagiac wells show a greater thickness of blue calcareous shale with no red shale mentioned, while from Coldwater and Elkhart no Traverse is reported. The Niles well in Volume V gives 415 to 500 ft. of very similar strata.		
Dundee (Carboniferous) limestone:		
Sample missing. Said to be similar to those below.....	13	696
Limestone, very white, clear, fiercely eff. in acid, leaving a little quartz sand residue.....	15	711
"Salt sand," here a brine was struck which filled up the hole about 400 ft., no casing done when the well was shot.		
Five samples, all yellowish, fiercely eff. limestone with a little quartz and microcline sand and more chert.....	45	756
At bottom, "oil sand."		
Limestone; record says "blue shale," but sample is a coarsely chipping, fiercely eff., somewhat darker limestone, struck together with gypsum, possibly from the brine.....	7	763

St. Joseph. In St. Joseph, across the river from Benton Harbor, Vincent and Blake drilled a well 820 feet deep penetrating the Dundee. The record compiled by A. C. Lane from a meager set of samples is given below. The drift is much deeper in the St. Joseph well than in the Benton Harbor well. The record does not agree very well with that of the Benton Harbor Natural Gas & Oil Co. well and, according to Lane, the latter may be imperfect.

ST. JOSEPH WELL.

(U. S. Geological Survey Well No. 233.)

	Thick- ness, feet.	Depth, feet.
Surface:		
Sandy drift clay.....	50	50
Rusty, sandy, with a variety of pebbles.....	50	100
Bluish drift clay, sandy.....	80	180
Richmond or Berea?		
Rusty red.....	5	185
Record missing from 185-500.		
Antrim shale:		
Dark shale.....	20	520
Traverse not represented by samples but it probably lies between 520 and 750 ft.		
Dundee? (Corniferous) limestone.		
Mixed. Very white and pyritiferous, dark and fiercely eff.....	70	820

Constantine. A well over 1080 feet deep was drilled many years ago at Constantine, and the record as correlated by A. C. Lane is given below.

CONSTANTINE WELL.

Levi Dodge, owner?

Elevation 803 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand.....	40	40
Blue clay.....	15	55
Sand.....	2	57
Blue clay.....	43	100
Sand.....	1	101
Hard pan.....	35	136
Coldwater shales:		
Soft "slate" or soapstone.....	150	286
Berea horizon:		
Red shale.....	16	301
Antrim shale:		
Gray "slate".....	91	392
Black shale.....	311	703
Traverse and Dundee.....	377	1080 +
Limestone, brine at 790 ft. with H ₂ S.		

KALAMAZOO COUNTY.

Kalamazoo. In 1887, the Kalamazoo Natural Gas Co. sunk a well 2250 feet for gas. A strong brine was struck in the top of the Dundee at about 1270 feet and brine and a little oil at 1490 feet near the top of the Monroe.

KALAMAZOO WELL.

Kalamazoo Natural Gas Co. Drilled in 1887. Record in part from samples.

Elevation 771 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface (approximately, P. B. Beardsley).....	130	130
Coldwater Shales:		
Clay and shale (soft); drab color.....	170	300
Black sandstone (hard).....	20	320
Dark blue shales (soft).....	300	620
Red clay.....	110	730
Light blue soft shale.....	200	930
Berea?		
Twenty ft. of red clay between 900 and 1000 ft.....	20	950
Antrim shale:		
Dark drab soft shale.....	120	1070
Black slate, soft and somewhat sandy.....	130	1200
Traverse (Hamilton) Formation:		
Limestone, blue and hard.....	60	1260
Blue slate and shale, soft.....	10	1270
Dundee (Corniferous) limestone:		
Light gray sandstone, hard. Strong brine (probably cherty limestone).....	40	1310
Limestone, briskly eff., light buff.....	180	1490
Monroe Formation:		
Gypsiferous dolomite, anhydrite, with strong brine.....	25	1515
Very salty, i. e., brine, from 1270-1740 ft.		
Flow of brine also from 1610-1635 ft.		
Salt and oil at 1490 ft.		
Mainly ferruginous dolomite with anhydrite.....	215	1730
Niagara (Guelph and Lockport):		
White dolomite.....	145	1875
Red sandy shale.....	45	1920
White sandstone.....	50	1970
Red sandstone.....	30	2000
Rochester:		
Dark shale.....	80	2080
Clinton:		
Dark gray dolomite, eff. moderately.....	40	2120
Light to buff dolomite, eff. slowly; small clay and quartz residue, ferru- ginous.....	110	2230
Medina:		
Brown sandstone, with a little calcite, rounded quartz and angular fel- spar, including microcline.....	20	2250

CHAPTER VIII.

WESTERN MICHIGAN.

MUSKEGON COUNTY.

Muskegon. Along the shore of Lake Michigan from Muskegon north to Manistee and beyond, a large number of deep wells have been drilled since the early 70's for salt, water, and oil and gas. At Muskegon, there are a number of wells, some of which penetrate the Marshall for fresh water, while others reach depths of 1400 to 2400 feet.

The oldest and farthest west of these deep wells is the Whitney or Truesdell, also called the Hacker well. It is located close to the lake at an elevation of about 586 feet. A. T., and according to reports is from 1230 to 1600 feet deep. Copious flows of water were struck at 330 feet, and also at 643 feet, the lower one being mineralized but of agreeable and refreshing taste. Strong brine was struck at the bottom, probably in the Monroe beds, but this did not rise and mingle with the water above.

The Mason well near the old Occidental Hotel, 613 ft. A. T., was begun 1872 and a depth of 2000 feet was reached two years later. In 1875, it was 2400 feet deep and was finally bottomed in the Salina at 2627 feet. An abundance of artesian water and brines was struck, and at 1200 feet oil and gas. At first, the quantity of oil was reported to be 75-100 barrels per day, but the flow proved to be mainly water mixed with a little oil. From the quality of the oil, the horizon then appeared to be that of the Berea grit, but later the much more accurate record of the Central Paper Company well indicates that the oil horizon is in some fine grained grits or sandstones in the base of the Coldwater, but at some distance above the Berea horizon. A strong brine resembling the Dundee was struck at about 2030 feet in rock containing thin beds of sandstone. No rocks typical of the Dundee were recognized and perhaps the formation is absent, since it is known to decrease in thickness toward the western part of the State, and it is absent at Milwaukee on the opposite side of Lake Michigan.

THE "MASON" WELL.

Loc.: Near Old Occidental Hotel. Mason Lumber Co. Drilled in 1875.

Elevation of well 594 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand.....	60	60
Clay.....	150	210
Hardpan.....	15	225
Napoleon or Upper Marshall:		
Sandrock with seams of iron pyrites and some shale.....	100	325
Lower Marshall and Coldwater:		
Shales and sandrock alternating.....	300	625
Overflow of water just above 625 ft.; some of the rock dark gray and shale.		
Blue shale, with streaks of some soft material.....	775	1400
Sandstones and limestones from 625 to 685 ft.		
Strong flow of mineral water at about 685 ft.		
Red rock not far from 900 ft. probably.		
Fine grained grits and sandstones, probably at about 1200 ft. Petroleum and gas. Good lubrication oil. Cf. Central Paper Co. well.		
Antrim shale:		
Solid blue shale.....	150	1550
Solid red shale.....	150	1700
Traverse (Hamilton) Formation:		
Limestone, with streaks of shale and soft limerock.....	300	2000
Salt bearing rock, with streaks of sand (Dundee?), 1 to 4 ft. thick.		
Cannot say whether salt was struck or not. Brine 100°.....	50	2050
Dundee not recognized unless it is this sandy horizon.		
Light colored limerock and shale.....	50	2100
Mouroe Formation:		
Dark colored limerock, (dolomite probably and so indicated in a section drawn under Wright's direction).....	250	2350
Salina:		
Gypsum and lime streaks, 4 to 6 ft. thick.....	50	2400
Limerock and gypsum, a little less gypsum than in preceding and more lime.....	145	2545
Rapid and various changes ending in dark limerock, loose and porous.....	82	2627

The Ryerson-Hills well, farther east at about 588 feet A. T. is complete in its record only to 1427 feet, but it was drilled to between 2050 and 2200 feet. A flow of brine, probably at about 2050 feet, was struck, yielding about one-third of a barrel per minute when pumped rapidly. Oil was found at about 1200 feet, but this horizon was cased off and the well continued to the deeper brine horizon. In 1900, the well was cleaned out, plugged at 1200 feet, and tested for oil. Only a little was obtained but, after the well was abandoned, the brine which came to the top of the casing had a layer of oil on it, and, according to recent reports, oil and a little gas has been constantly seeping from the well.

RYERSON-HILLS WELL.

Elevation 588 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	65	65
Clay.....	135	200
Hardpan.....	8	208
Hardpan, sandy spots and shale.....	90	298
Lower Marshall and Coldwater:		
Dark and light shale.....	200	498
Lime.....	4	502
Shale.....	20	522
Lime.....	1	523
Light shale.....	20	543
Lime.....	2	545
Light olive shale.....	40	585
Lime.....	2	587
Light blue shale.....	15	602
Hard lime rock.....	80	682
White and blue shale and streaks of lime.....	195	877
Red shale.....	8	885
Hard lime.....	3	888
Dark and light shale.....	222	1110
Lime.....	5	1115
Loose shale.....	312	1427
Depth reported 2050 to 2200 feet. Record from 1427 feet unknown.		

Close to the lake and near the Ryerson, another well was drilled in 1900. The record, not kept in detail, is said to be very similar to the former. A little oil and salt water were struck at 1227 feet. About the same time, another well 12 feet above the lake was drilled only 44 feet southwest of the Mason well for the Michigan Oil Company. Prof. McLouth kept a careful record with a number of samples. At 1275 feet, a fine grained micaceous sandstone or sandy shale, the oil horizon of the other wells, was struck and this yielded a little oil.

MICHIGAN OIL COMPANY WELL.

Loc.: Forty-four feet southwest of the Mason well.

Elevation 592 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand becoming finer downward.....	60	60
Calcareous blue clay free from pebbles.....	163	223
Gravel in clay and sand, till.....	12	235
Upper Marshall:		
White micaceous sandstone.....	105	340
Lower Marshall and Coldwater:		
Blue micaceous shale; drilled 65 ft. in 7 hrs.....	280	620
Harder shale with carbonates of iron and lime; drilled 70 ft. in 10 hours.....	80	700
Soft blue shale, calcareous.....	190	890
Brown limestone.....	24	914
Flagstones, shales with thin laminae of white sandstone and calcareous bands; drilled 40 ft. in 4½ hours, and 6 ft. in 33½ minutes.....	361	1275
White very fine grained micaceous sandstone or silicious shale, yielding a little oil.....	18	1293
Sandy shale.....	27	1320
Shale, somewhat darker at bottom.....	180	1500

Later the Central Paper Company¹ drilled a well 1650 feet deep on Lot 1, N. E. $\frac{1}{4}$ sec. 34, T. 10 N., R. 17 W., about $4\frac{1}{2}$ miles from the Ryerson well. This well appears to be at about the same altitude as the Ryerson, and 10 feet lower than the Mason. A careful log was kept and a good set of samples obtained.

As the well is at a considerable distance from the Ryerson, the Mason, and other wells, determinations of the local dips and structures can be made. From Milwaukee, where the edge of the Traverse or Hamilton rocks outcrop at the surface, across Lake Michigan to Muskegon it is approximately 86 miles. At Muskegon, the Traverse appears to be 1700 feet below the surface, therefore the dip from Milwaukee eastward to Muskegon is about 20 feet per mile.

The base of the Antrim black shale occurs in the Central Paper Co. well at 1615 feet and in the Mason at 1700 feet. The latter well is about 10 feet higher in elevation, and, allowing for this, there is a drop in the strata of approximately 75 feet in about four miles. This gives a dip of nearly 20 feet per mile to the eastward, which corresponds with the general dip from Milwaukee to Muskegon.

In the Central Paper Co. well, a bed of red fossiliferous limestone occurs from 845 to 870 feet, and this also occurs from 890 to 904 feet in the well, drilled in 1900 near the old Mason well. In this case, the drop is about 45 feet in four and one-half miles or an average of only 10 feet per mile.

The Central Paper Company, Ryerson-Hills and Mason wells are not in direct line, but they are nearly so and, from the general eastward dip, the strata in the Ryerson should be lower than in the Mason well. On the contrary, the red horizon and other corresponding strata are higher in the Ryerson than in the well drilled in 1900 close to the old Mason well. This indicates a local disturbance in the rock strata, and, according to Lane, the chances for finding a pronounced anticlinal appears to be greater farther north along Muskegon lake, perhaps on the north side in sections 15 and 16. Unfortunately, the oil sand is so fine grained that probably the flow would be limited unless the oil stratum should be struck in a coarse phase.

Beneath this oil horizon, however, are those of the Traverse and perhaps the Dundee. The Traverse is well represented by an alternation of limestones and shales, the latter mainly blue. Possibly, as at Saginaw, some of the limestones may contain oil. As the Dundee is thin, or possibly not present at Muskegon, this formation does not offer great possibilities, but the porous brine bearing stratum at the point, where the Dundee should be expected to occur, may prove to be oil and gas bearing.

¹Ann. Rept. 1903, p. 274.

CENTRAL PAPER CO. WELL.

Loc.: On Lot 1, N. E. $\frac{1}{4}$, sec. 34, T. 10 N., R. 17 W., about 4 $\frac{1}{2}$ miles from Ryerson-Hills well.

Elevation of well 584 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	50	50
Red calcareous clay.....		
Smooth, red calcareous clay.....	183	233
Lower Marshall sandstone:		
Sandstone, greenish, calcareous, very fine at the bottom; a typical Mar- shall grit.....	77	310
Coldwater shale:		
Shale, dark, bluish, more or less calcareous.....	315	625
Limestone, a clayey and dolomitic water lime, with selenite; like lime- stones of the Michigan series.....	35	660
Shales, blue calcareous.....	185	845
Limestone, red and white, fossiliferous.....	25	870
Flags, i. e., blue and green silicious shales, with bands of very fine- grained grits, or sandstone; in places more or less calcareous.....	530	1400
Berea Horizon:		
Shales, red and green.....	80	1480
Antrim shale:		
Shale, black, bituminous, pyritic, especially at the base.....	135	1615
Traverse (Hamilton) Formation:		
Shale, blue, calcareous.....	35	1650

Fruitport. At Fruitport in the southern part of Muskegon county, a deep well was drilled about 1903, but the samples preserved for the Michigan Geological Survey were carried away by mischievous boys and no record was kept by the drillers.

MASON COUNTY.

Ludington. At Ludington, several deep wells (Fig. 15) were drilled to the Salina for salt by the lumber companies in the early days of the salt industry.

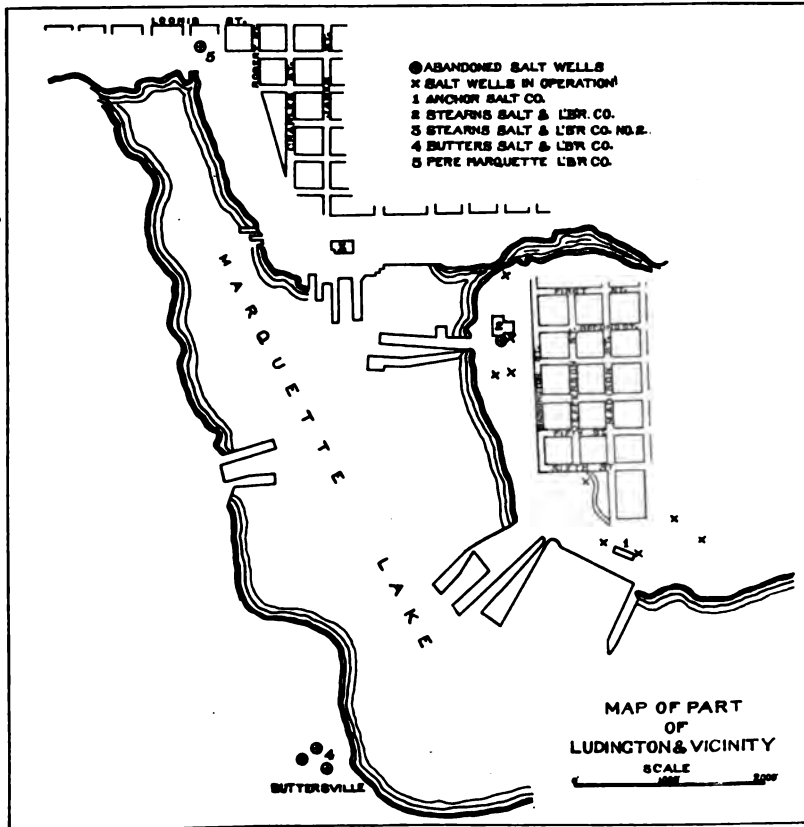


Figure 15. Map of a portion of Marquette Lake, Mason county, showing location of salt blocks (after C. W. Cook.)

The Pere Marquette Lumber Company's well at the north end of Marquette lake, 2220 feet deep, (490 ft. A. T.) and the Butters and Peters well on the southwest side of the lake, 2260 feet deep, penetrated rock salt in the Salina, but apparently no oil or gas was found.

PERE MARQUETTE LUMBER CO. WELL.

Loc.: Near mill at the north end of Marquette lake, Ludington; 1½ miles north of Butters and Peters well. Drilled in 1885. Record in part from samples.

Elevation 590 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	30	30
Marl, shells and pine sticks.....	5	35
Sand.....	21	56
Soft clay.....	4	60
Hard clay.....	20	80
Hard pan.....	10	90
Coarse sand and small stones.....	18	108
Sand and gravel.....	9	117
Sand.....	42	159
Sand and gravel.....	24	183
Sand with clay.....	17	200
Sand.....	5	205
Clay.....	4	209
Clay and gravel.....	5	214
Clay and sand.....	27	241
Hard pan.....	32	273
Clay.....	11	284
Clay and gravel.....	8	292
Clay.....	15	307
Clay and gravel.....	53	360
Clay.....	37	397
Clay and sand.....	15	412
Hard clay.....	52	464
Hard pan and gravel.....	12	476
Gravel.....	16	492
Gravel and sand.....	6	498
Sand.....	18	516
Gravel and clay shale.....	12	528
Coldwater shale:		
Blue shale.....	35	563
Limestone.....	15	578
Red shale and marl.....	8	586
Shale.....	8	594
Limestone.....	5	599
Blue shale.....	601	1200
In Lyon's No. 2 well, a showing of oil at 1175 ft.		
Antrim shale:		
Black slate or hard shale, with pyrite.....	165	1365
Traverse (Hamilton) Formation:		
Blue shale and limestone.....	70	1435
Black sandy limestone, with strata of gypsum.		
The limestone is quite crystalline at a depth of say 1460 ft. There are many specks of pyrites.....	45	1480
Brine 30°.....		
Limestone.....	60	1540
Limestone and gypsum.....	20	1560
Limestone, hard with grit above, and softer with less grit below.....	240	1800
Brine 30°-36°.....		
Blue shale.....	58	1858
Salt; either salt (?) or soft salt rock.		
90° brine.....	4	1862
Limestone, very sticky. 70°-80° brine.....	100	1962
Slow eff. with some sand grains at 1880 feet.		
Bluish, argillaceous, moderately eff. with a large residue 1920-2005 ft.		
Dundee? (Corniferous) limestone:		
Very hard limestone. 20° brine.....	40	2002
Dolomitic limestone, with a residue of quartz sand and anhydrite.		
Monroe Formation:		
Dolomite, with soft streaks. 6 in. to 18 in. thick, 50°-56° brine.....	138	2140
Brisk eff. 2005-2050 ft.		
Mainly rounded sand, eff. slowly at 2100 ft.		
62°-64° brine.		
Largely rounded sand. Eff. slow at 2150 ft.		
Rusty white sand 2125-2220 ft.		
Hard gray limestone, contains gypsum and is soft in streaks.....	55	2195
Salina:		
Rock salt. 100° brine.....	18	2213
Limestone, containing 2 feet of rock salt.....	7	2220

In the Lyons No. 2 well, a showing of oil was reported at 1175 feet which should be near the base of the Coldwater, possibly in some of the thin stray sandy layers which in the western part of Michigan locally occur in this formation near the Berea horizon.

A few years ago the J. S. Stearns Lumber Company drilled a well 2304 feet in depth to the rock salt of the Salina. An accurate record and set of samples were kept from which it appears that an oily brown limestone occurs at 2085 feet in the upper part of the Traverse, while the middle Traverse is composed of 250 feet of pure limestone. Part of the latter may be the Dundee, but the recognition of this formation is not certain in this well.

J. S. STEARNS SALT & LUMBER CO. WELL.

Loc.: Ludington plant. One mile north of Butters and Peters well and on north side of Marquette Lake. Record by Lane.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	198	198
10 in. casing to 204 ft.		
Pink clay, calcareous.....	68	266
Water at about 300 ft., T. 53°.		
Gravel.....	94	360
Pink clay, calcareous.....	155	515
Gravel.....	61	576
8 in. casing to rock.		
Coldwater shale:		
Limestone.....	74	650
With 15 ft. of porous granular limestone and salt water 35 ft. below the casing.		
Blue shale.....	550	1200
Antrim shale:		
Black shale.....	200	1400
Traverse (Hamilton) Formation:		
Brown limestone.....	25	1425
Blue shale.....	35	1460
Brown limestone, oily with H.S.....	40	1500
Pure limestone (possibly Dundee?—Lane).....	250	1750
Brown sandy dolomite.....	160	1910
Calcareous shals (Bell or Marcellus).....	90	2000
Monroe Formation (Dundee in part?):		
Dolomite.....	25	2025
Limestone (Anderson or Dundee—Lane).....	25	2050
Dolomite.....	25	2075
Sylvania sandstone?.....	100	2175
Sandy dolomite and anhydrite.....	121	2196
Salina:		
Salt.....	8	2304

The Anchor Salt Co.⁴ has drilled five wells to the salt beds. The No. 3 well, 2360 feet in depth, shows three beds respectively 20, 9, and 8 feet thick and the No. 5, four beds 20, 12, 7, and 5 feet thick. The records of No.'s 4 and 5 are given below.

⁴C. W. Cook, Brine and Salt Deposits of Michigan, Pub. 15 Geol. Ser. 12; Mich. Geol. and Biol. Surv., 1913, pp. 157-159.

ANCHOR SALT CO. WELL NO. 4.

Loc.: Ludington, on north side of Marquette lake three-fourths mile northeast of Butters and Peters well. Completed in 1908, J. H. Brogan, driller. Record by P. Hardy.

Elevation between 635 and 650 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene drift:		
Sand and gravel	267	267
Clay	27	294
Hardpan	19	313
Clay	36	349
Sand	89	438
Clay	5	443
Hardpan and sand	25	468
Sand	40	508
Hardpan and gravel	2	510
Sand	4	514
Gravel	4	518
Sand	34	552
Gravel	6.5	558.5
Brown shale	3.5	562
Sand	1	563
Shale	10	573
Sand and gravel	2	575
Coldwater:		
Shale (Hard Illinois till from 558.5 to 635 ft.? Depth to rock uncertain from record)	60	635
Limestone	14	649
Hard "slate" (shale)	24	673
Limestone	6	679
Red limestone	17	696
Lime	74	770
Sharp lime (sandy or cherty?)	112	882
Lime	18	900
Shale	167	1067
Lime	20	1087
Shale	146	1233
Antrim shale:		
Black shale	29	1262
Brown shale	176	1438
Black shale	58	1496
Traverse (Hamilton) and Dundee?:		
Lime, water at 1536 ft.	44	1540
Lime, "Trenton." Water at 1569 ft.	37	1577
Brown sandstone	108	1685
Gypsum (anhydrite?) at 1586 and a vein of sand at 1617 ft.		
Sharp sandstone	10	1695
Black sandstone	46	1741
Sharp sand	29	1770
Black sand	8	1778
Brown sand	57	1835
Dark sand	13	1848
Sharp sand	8	1856
Black sand	9	1865
Brown sand	20	1885
Yellow sand	33	1918
Brown sand	34	1952
Black sand	27	1979
Sharp sand	7	1986
Probably the "sand" from 1540 to 1986 is dolomite, cherty or sandy in the "sharp" horizon.		
Streak of shale	3	1989
Limestone	6	1995
Shale	69	2064
Dundee (?) and Monroe:		
Black lime	10	2074
Brown lime	235	2309
Salina:		
Salt	20.5	2329.5
Bottom of salt at 2329.5 ft.		

ANCHOR SALT CO. WELL NO. 5.

Log furnished by J. H. Brogan, driller.

Elevation about 595 (?) ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	90	90
Gravel.....	42	132
Sand.....	92	224
Gravel and hardpan.....	176	400
Sand.....	90	490
Blue clay.....	44	534
Coldwater:		
Slate (Hard Illinoian till?).....	61	595
Blue lime.....	15	610
Slate and limestone (in part Antrim).....	725	1336
Antrim shale:		
Brown shale.....	147	1482
Traverse (Hamilton) Formation:		
Hard limestone.....	468	1960
"Cave" (Soft shale? Bell shale? Cf. well No. 4).....	70	2030
Dundee (?) and Monroe:		
Hard limestone, Dundee not recognized.....	233	2263
Salina:		
First salt.....	20	2283
Hard white lime.....	14	2297
Second salt.....	12	2309
Limestone.....	25	2334
Third salt.....	7	2341
Limestone.....	13.9	2354.9
Fourth salt.....	5	2359.9
Limestone.....	44.9	2404.8

The No. 3 well with a total depth of 2360 feet showed three beds of salt, respectively 20, 9, and 8 feet in thickness. This well which has about the same elevation as No. 5 is located about 1,000 feet west and 700 feet north of it.

MANISTEE COUNTY.

Manistee. In the Manistee salt district, there are more than 35 deep wells scattered from the shore of Lake Michigan along Manistee lake to Filer City and Stronach, a distance of four or five miles. Below is a list of 29, giving locations and depths as far as obtainable. The records of many of them are very incomplete, only the depth to the salt or the total depth being known.

Number.	Owner.	Location.	Elevation above lake. Feet.	Total depth. Feet.	Depth to top of salt rock. Feet.
1	Canfield & Wheeler No. 1...	0.7 mi. N., 0.68 mi. W., sec. 11, T. 21 N., R. 17 W.	12	2,700	1,900
2	Canfield & Wheeler No. 2...	0.7 mi. N., 0.68 mi. W., sec. 11, T. 21 N., R. 17 W.	12	1,947	
3	Manistee Lumber Co. No. 1	28.72 sec. 1		1,926	
4	Manistee Lumber Co. No. 2	28.72 sec. 1			
5	Louis Sands No. 1	04.44			
6	Louis Sands No. 2	04.44			2,012
7	Canfield S. & L. Co.	1.08, sec. 1			
8	Canfield S. & L. Co.	1.08, sec. 1			
9	R. G. Peters No. 1	92.28, sec. 7, T. 21 N., R. 16 W.		2,026.5	
10	R. G. Peters No. 2	92.28, sec. 7, T. 21 N., R. 16 W.			
11	R. G. Peters	92.28, sec. 7, T. 21 N., R. 16 W.			
12	R. G. Peters	92.28, sec. 7, T. 21 N., R. 16 W.			
13	R. G. Peters	92.28, sec. 7, T. 21 N., R. 16 W.			
14	Buckley & Douglass	54.40, sec. 12, T. 21 N., R. 17 W.			
15	Buckley & Douglass	54.40, sec. 12, T. 21 N., R. 17 W.			
16	Buckley & Douglass	54.40, sec. 12, T. 21 N., R. 17 W.			
17	Buckley & Douglass	54.40, sec. 12, T. 21 N., R. 17 W.			
18	Buckley & Douglass	54.40, sec. 12, T. 21 N., R. 17 W.			
19	Canfield S. & L. Co.	18.36 sec. 7, T. 21 N., R. 16 W.	30	2,015	1,965
20	Canfield S. & L. Co.	18.36 sec. 7, T. 21 N., R. 16 W.		1,947	
21	State Lumber Co.	18.21 sec. 12, T. 21 N., R. 17 W.			
22	State Lumber Co.				
23	State Lumber Co.				
24	Louis Sands	69.07 sec. 18, T. 21 N., R. 16 W.			
25	Louis Sands				
26	Filer & Sons	96.86 sec. 19 T.			
27	Union Salt & Lumber Co.	72.68 sec. 20	25	1,982	1,924
28	Union Salt & Lumber Co.	72.68 sec. 20		or 2,016 to 2,025	
29	East Lake or Percy	East Lake		2,045	2,025

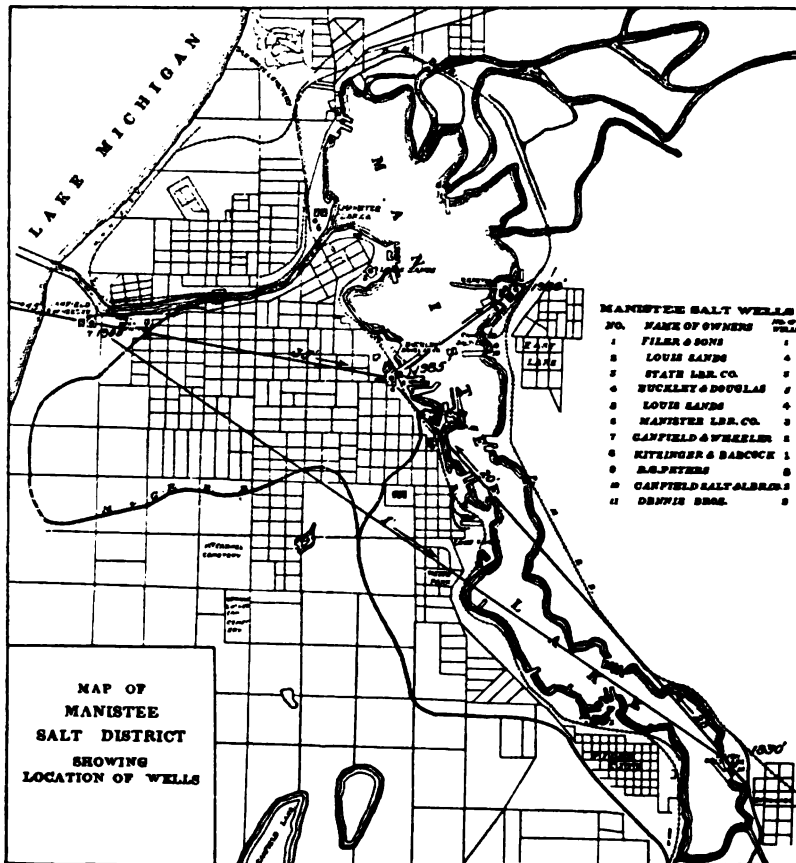


Figure 16. Map of the Manistee salt district showing location of salt wells and the discordant dips of the salt horizon and depths to the same. Arrows indicate direction and numbers, amount of dip per mile.

The Canfield-Wheeler well (592 A. T.) near Lake Michigan (see Fig. 16), originally 1947 feet deep, was afterwards deepened some 500 feet by T. Percy to the white Guelph or Niagara dolomites. These outcrop on the opposite shore of lake Michigan and, according to computations by Lane, the dip across the lake is not less than 39 feet nor more than 50 feet per mile. This dip is intermediate between the 20 foot dip from Milwaukee to Muskegon and the 60 foot one from Neebish Island to Cheboygan. A second well was drilled but only to 1926 feet.

CANFIELD-WHEELER WELL.

Loc.: Near mouth of Manistee River, Manistee. Record by E. D. Wheeler; notes on samples by Lane. (Samples appear to have been mixed.—Lane.)

Elevation 604 ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand, with streaks of gravel	93	93
Reddish gray clay	2	95
Sand	107	202
Gray clay	94	296
Dark reddish clay	2	298
Quicksand	3	301
All shades of clay; some sand	54	355
Gravel	3	358
Clay, sand, gravel	36	394
Reddish clay, gravel and some sand	181	575
Dark clay and gravel	5	580
Dark shaly stuff	15	595
Light shaly stuff	7	602
Shale and gravel. Contains pebbles of white limestone, argillaceous marl; large residue of clay	113	715
Richmondville or Berea?:		
Sandrock, with occasional streaks of shale and lime	160	875
Antrim shale:		
Shale and streaks of hard lime. (Traverse in lower part)	200	1075
Light gray limestone and some black shale; medium residue of glassy grains of quartz and black slate at 965 ft. (Base of Antrim?)		
Grayish calcareous sandstone; large residue of small rounded grains of glassy silica at 1020 ft.		
Light gray limestone, medium residue of milky quartz, glassy quartz and black slate at 1040 ft.		
Traverse (Hamilton) Formation:		
Blue shale	380	1455
Bluish gray argillaceous marl; large residue of clay at 1100 ft.		
Light gray and dark brown limestone; medium residue of glassy quartz and black slate at 1145 ft.		
Hard gray and black limestone, with conchoidal fracture; also black and light gray slate at 1290 ft.		
Bluish? argillaceous shale and light gray limestone; also black shale at 1310 ft.		
Limestone as at 1290, and a little blue shale at 1325 ft.		
Light gray marl; very small siliceous residue at 1370 ft.		
Siliceous limestone and marl; residue of glassy quartz and gray and dark gray lumps at 1410 ft.		
Calcareous clay; large residue of clay at 1420 ft.		
Bluish gray calcareous clay; residue of clay 90 per cent at 1432 ft.		
Bluish gray calcareous clay; residue of clay 90 per cent at 1455 ft.		
Sticky grayish brown shale, cased 60 ft. above bottom when hole was 1520 ft. deep; brine 20 per cent.	100	1555
This sample came up in the slops (i. e. on the sinker rods) when the hole was down 1510 ft. and is like previous sample.		
Bluish gray argillaceous shale; residue of clay 95 per cent at 1525 and 1530 ft.		
Shaly lime	20	1575
Dundee (Corniferous) limestone:		
Lime rock	29	1604
Reddish limestone, with numerous yellow specks of ochre; small residue of clay and silica at 1620 ft.		
Shale and lime	51	1655
Lime streaks, dark and light	40	1695
Yellow gray silicious limestone; appears quite friable; medium residue silicious and yellow at 1675 ft.		
Monroe Formation:		
White lime; brine 30 per cent from here to 1845 ft. Grayish white calcareous clay at 1200 ft.; large residue	10	1705
Lime and shale, hard	20	1725
Shaly and sticky	15	1740
Light gray argillaceous marl at 1735 ft.; large residue of clay and gypsum		
Dark buff soft limestone at 1740 ft., as at 1675; medium residue of clay and gypsum		
Lime cuts free	5	1745

CANFIELD-WHEELER WELL.—Concluded.

Elevation 604 ft. A. T.	Thick- ness, feet.	Depth, feet.
Calcareous shale.....	7	1752
Very hard spots and softer, and streaks of lime.....	28	1780
Very hard streaks, with streaks of softer.....	23	1803
Porous rock:		
Dark gray or drab dolomite at 1810 and 1825 ft.; very small residue, saline.....	32	1835
Porous rock:		
Dark drab dolomite, conchoidal fracture; very hard; very small resi- due at 1835.....	10	1845
Clay lime rock with hard thin streaks. Brine 80°; light gray soft lime- stone at 1845 ft., small residue of gypsum and silica.....	13	1858
Softer; cuts very fast from 1845 to 1858.		
Soft lime rock:		
Dark drab dolomite at 1858, as at 1835 ft.....	7	1865
Hard and soft streaks. Brine 92°.....	10	1875
Massive lime rock. 93° S. 1877 ft. similar to 1858 ft., and a yellowish limestone in small grains; very small residue.....	25	1900
Supposed to be salt. 96%.....	4	1904
Samples missing from 1904 to 1912 ft.		
Salina:		
Rock salt.....	30	1942
Hard lime rock.....	5	1947

Buckley & Douglass Lumber Co. drilled five or more wells, but only of the No. 5 was a complete record obtained. According to Mr. J. J. Hubbell, the record is as follows.

BUCKLEY & DOUGLASS LUMBER CO. WELL NO. 5.

Elevation about 610 ft. A. T.	Thick- ness, feet.	feet. Depth,
Pleistocene:		
First casing 10-inch pipe driven 400 ft.....		400
Second casing 8-inch pipe to bed rock through sand, clay and gravel....	616	616
Antrim shale:		
Hard shale.....	324	940
4½ inch casing to 985 ft.		
3 inch casing to 1032 ft.		
A 3 inch pipe for brine inserted 985 ft.		
Traverse and Dundee:		
Limestone.....	630	1570
Soft shale, 7 inch hole drilled, brass lining to caving rock.....	110	1680
Monroe Formation:		
Limestone, 6 inch hole, no lining.....	195	1875
Salina:		
Six inch hole brass lining, caving rock salt and gypsum.....	20	1895
Limestone, 5 inch hole, no lining.....	90	1985
Brine cavity.....	30	2015

The above well is near Manistee Lake about 1½ miles east of the Canfield-Wheeler, 610 ft. A. T. or about 18 feet higher, but the top of the salt at 1985 feet seems to be fully 70 feet deeper. Too much dependence must not be placed upon comparisons between these two wells as the record of the Canfield is probably not reliable, since the samples do not correspond with the log.

East Lake. The R. G. Peters Salt & Lumber Co. in East Lake is

about three-fourths of a mile northeast of the Buckley and Douglass Lumber Co. The Peters Company drilled a well in 1886 and according to the record of this published in Volume V (Pl. XXXII) the top of the first salt bed occurs at 1988 feet, or practically at the same depth as in the Buckley and Douglass well. In the former, the base of the Antrim appeared to be at 960 feet, in the latter 940 feet. A soft shale from 1570-1680 feet may likewise be correlated with a similar shale in the Buckley-Douglass at 1490-1600 feet. The top of the salt in the Canfield and Wheeler well near Lake Michigan occurs at 1932 feet, hence the salt is about 70 feet deeper in the Buckley and Douglass well. This is equivalent to a dip of about 35 feet per mile slightly south of east. This dip is comparable to the average south-east dip of the Niagara of 39 to 50 feet per mile across Lake Michigan. From the Buckley and Douglass well northeast to the R. G. Peters well the dip is nearly if not quite flat (Fig. 16), assuming that the salt beds are the same in each well. Considerable oil and a great pressure of gas were encountered at 1905 feet in the old R. G. Peters well. Water and oil, according to reports, shot up 150 feet above the derrick, blowing off the top. Some oil was also reported in the Antrim shale at about 960 feet.

R. G. PETERS LUMBER CO. WELL.

Manistee No. 3 of Vol. V. Pl. XXXII.

Loc.: East Lake, Manistee. Drilled in 1885. Driller's record with correlations by C. E. Wright. No samples.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Sand, gravel and clay.....	614	614
Antrim:		
Black shale, in part bituminous. Some petroleum. Black water at 960 ft.....	346	960
Traverse (Hamilton):		
Limerock, hard and salt, light colors.....	530	1490
Argillaceous shale (Bell shale), caves badly; looks like petrified worm-holes; dissolves readily in water.....	110	1600
Dundee and Monroe:		
Sandy limestone. Dundee cannot be distinguished from Monroe. First showing of oil at 1905.....	305	1905
Water and oil shot up from the 8 in. casing to 150 ft. above the surface; blew off the top of the derrick.		
Record missing from 1905 to 1988 feet.		
Salt to hard rock below.....	38	2026
Top of salt at 1988 ft.		

In 1908, another well was drilled by the R. G. Peters Salt & Lumber Co. to the salt bed and a set of samples and a log were preserved, from which the appended record has been compiled. According to Mr. R. A. Nickerson, general manager of the company, a considerable flow of oil was struck at 1925 feet, which was immediately cased off

and the well continued to the salt bed, which was struck about 1980 feet.

R. G. PETERS SALT & LUMBER CO. WELL NO. 7.

Loc.: N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, sec. 7, T. 21 N., R. 16 W., East Lake. Record from samples and notes, furnished by R. A. Nickerson, General Manager. Samples examined by Lane.

Elevation 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface	503	593
Antrim:		
Soft blue shale	4	597
Bluish gray calcareous shale, gas at 730 ft.	203	800
Hard black micaceous shale	187	987
Traverse (Hamilton) Formation:		
Fine gray cherty limestone, vigorous eff. Some blue shale	347	1325
Very hard geodiferous dolomite with pearl spar in geods at 987 feet, gas at 1100 feet.		
Black shale and gray limestone with selenite (gypsum) crystals; vig. eff.	75	1400
Gray limestone (Vig. eff.) and a little black shale; selenite. Harder than at 978.	25	1425
Mainly light gray limestone (Vig. eff.) with a little black shale. Selenite.	25	1450
Gray to dark gray and black shale	37	1487
Dark gray shale and light gray argillaceous limestone. Top of cave rock; mod. eff. and very pyritic; selenite.	13	1500
Soft gray calcareous shale	50	1550
Crumbly soft shale (Bell) resembling blue clay; some eff.	45	1595
Dundee (Corniferous) limestone:		
Hard gray to buff fine grained limestone; cherty (sand) and pyritic; violently eff.	10	1605
Reddish fine grained brown limestone sandy and cherty; very pyritic and ferruginous; mod. eff.	15	1620
Monroe Formation:		
Gray dolomitic limestone; pyritic and gypsiferous; some bituminous matter.	18	1638
Reddish anhydrite and dolomite, sand and selenite	7	1645
Anhydrite and dolomite, light buff in part.	7	1652
Ferruginous (altered from pyrite) buff dolomite, anhydrite, selenite. Gas at 1654 feet.	4	1656
Buff dolomite, anhydrite, selenite; some chert from 1638 to 1658 ft. Some bituminous matter.	5	1661
Pyritic buff dolomite with anhydrite and selenite; softer than above.	19	1680
Very red (ferric oxide from pyrite) anhydrite and dolomite; very fine grained.	20	1700
Mainly red (ferric oxide from pyrite) anhydrite, and some dolomite.	80	1780
Dolomite and anhydrite with selenite	30	1810
Brown dolomite and anhydrite, selenite, and a little dark shale.	10	1820
Mainly anhydrite, pyritous.	10	1830
Mainly pure anhydrite with a little black shale.	20	1850
Hard gray vesicular dolomite with selenite crystals.	12	1862
Cherty dolomite and anhydrite; "cave rock"	8	1870
Brown dolomite with much anhydrite and selenite.	10	1880
Vesicular grayish brown dolomite with selenite; ferruginous.	15	1895
Vesicular gray dolomite with much selenite in cavities.	10	1905
Mainly red (from altered pyrite) anhydrite and dolomite, gas rapidly increasing from 1911 to 1916. Quite a flow of oil from 1916 to 1925 feet.	25	1930
Mainly very red anhydrite and dolomite.	10	1940
Vesicular gray dolomite; selenite crystals; very salty.	20	1960
Dark gray porous limestone (dolomite)	20	1980
Salt	20	2000

In the Louis Sands Salt & Lumber Co. wells, in Manistee, gas has been reported in sufficient quantity to be utilized in a small way.

Stronach. The Stronach Lumber Co. wells at Stronach (604 ft. A. T.) are a little over $3\frac{1}{2}$ miles southeast of the Canfield-Wheeler and $2\frac{1}{2}$ miles from the Buckley and Douglass wells. The salt bed, 1930 to 1964 feet is about as high as in the Canfield and about 30

feet higher than in the Buckley and Douglass or in the Peters at East Lake. The Bell (Marcellus) shale from 1450-1625 feet likewise is higher and signs of oil and gas were encountered directly beneath this shale. The Antrim black shale, however, is at about the same depth, i. e. 970 feet. Gas was struck in the top of the black shales at about 600 feet and oil and gas about 30 feet below the top of the Dundee, which is cherty, porous and perhaps brecciated as it caves in some of the drillings. In the Union Lumber Co. wells (605 ft. A. T.), the top of the salt, reported at 1949 feet, is apparently a little deeper. The bottom was supposed to be at 1982 feet, but the bottom of the brine cavity deepened to 2015 and 2025 feet. This indicates that the bottom of the salt was not reached in the drillings.

The average dip of the formations, as previously noted, is between 39 and 50 feet per mile to the southeast. From this one would expect that corresponding strata at Stronach and Filer City should be from 150 to 200 feet deeper than near Lake Michigan in the Canfield-Wheeler well. On the contrary they are nearly as high at Stronach and Filer City as in the latter well, and are even higher than in the Buckley and Douglass and Louis Sands wells, which, although not in direct line, are between the Canfield and Wheeler and the Stronach wells. This indicates that there is an upward fold or anticline near Stronach which may contain oil and gas in commercial quantity. As there are no deep wells southeast of Stronach, one cannot tell whether the axis lies at Stronach or farther to the south and east.

Onkama. From the records of wells at Ludington and Manistee, it is to be observed that the drift is very thick, ranging from 500 to over 700 feet in thickness. It contains several thick beds of water bearing sand or gravel, and clay, some of which are probably persistent over large areas. As the black bituminous Antrim shale underlies these thick deposits in northern Manistee county, gas is commonly found with water in surface wells in small to very considerable quantities.

In the vicinity of Portage Lake, Manistee county, considerable gas mixed with water has been struck in many artesian wells throughout an area of four or five miles long. In 1901, a well in sec. 22, Onkama township, was drilled close to the fish hatchery on the north side of the lake. A strong flow of gas under high pressure was struck which, according to reports, rapidly decreased in pressure and volume. According to Mr. W. W. Davis, a well driller and contractor, who has drilled a great many of the artesian wells in the Portage Lake district in the past twenty years, the well caved below the bottom of the casing, which did not reach to the gas horizon, and thus the flow of gas was shut off. Other wells yielding much gas with water have been struck since then. In 1913, Mr. Davis made a test well near the fish



THE ONEKAMA GAS WELL, MANISTEE COUNTY.

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hatchery for Mr. H. Ward Leonard of Manistee. The well is located on the Northern Transportation Co. land about 25 feet from the old gas well. On January 27, 1913, gas with a pressure of about 185 pounds and free from water was struck at a depth of 437 feet in a sand or gravel bed. The casing is 2 inches in diameter and, in pulling out the well rods, the last 185 feet were blown free from the well and scattered around in the tree tops. The well was "blown" almost every day for several weeks from about 15 minutes to an hour and a half to prevent clogging. After it has blown for some time the pressure, measured by a registered steam gauge, gradually sinks to about 145 pounds but upon closing the valve the pressure is almost instantly back to 185 pounds or more. When the gas was lighted (Pl. III) the flame shot up 25 to 30 feet above the top of the casing.

The analysis of the gas, as furnished by Mr. Leonard, was made in 1913 at the Grand Rapids gas plant and indicates that the gas is of good quality and is free from sulphur.

ANALYSIS OF ONEKAMA GAS.

Carbon dioxide.....	0.2
Oxygen.....	1.1
Carbon monoxide.....	0.1
Nitrogen.....	11.7
Methane.....	86.0
Total	100.0
Heating power B. T. U (cu. ft.).....	1070.0
Candle power.....	3.0

There is much water in the overlying sand and gravels but it is shut off from the gas sand, which appears to be just below a compact conglomeratic mass of shale fragments. The following is the log as given by Mr. W. W. Davis, the driller.

LEONARD GAS WELL.

Loc.: Sec. 22, Onekama Twp., Manistee county. Owner, H. W. Leonard, Manistee; driller, W. W. Davis; 1912-13.

	Thick- ness, feet.	Depth, feet.
Red clay, gravel and sand.....	57	57
Blue clay.....	10	67
Sand.....	152	219
Layer of blue clay and sand.....	71	290
Red clay.....	120	410
Shale fragments with black water (sulphur water?).....	20	430
Gas bearing sand.....	7	437
Gas free from water and hydrogen sulphide gas. Flow of gas estimated at 4200 cu. ft. per min.		

The list of wells located around Portage Lake given below, with notes concerning the occurrence of gas was also furnished by Mr. Davis.

	Depth, feet.	Remarks.
Clark Well, Section 33.	470	Gas but no flowing water.
Sands & Smith Well, Section 33.	537	Gas and water.
August Lipkowski Well, Section 34.	418	Gas and water.
H. Ward Leonard Well, Section 32.	535	Gas and water.
Dunham Well, Section 28. Enough gas for one jet.	510	Trace of gas but no water.
Showalter Well, Section 25.	318	Trace of gas and good flow of water.
Dunham Well No. 2, Section 33.	425	No gas.
N. & M. Transportation Co. Well.	450	Gas and water.
Prosser Well, Section 35.	399	Very little gas.

From the abundance of gas in the sand and gravel beds in the region, it is probable that the body of gas described above is of considerable size and commercial importance, though as yet it has not been utilized.

CHAPTER IX.

NORTHERN LOWER MICHIGAN.

SURFACE DEPOSITS AND EXPLORATIONS.

The northern part of the Southern Peninsula has few and widely scattered deep drillings and these are chiefly near the lake shore at Frankfort, Petoskey, Charlevoix, Cheboygan, Onaway, Alpena, Grand Lake, Harrisville, Killmaster, Oscoda, Tawas City, Prescott and Standish. The only ones in the interior are the Hanson wells at Grayling and the Cadillac well, now being drilled.

As noted on previous pages, there is a broad belt extending from Newaygo, Mason and Manistee counties northeastward into Otsego, Montmorency, and Alcona counties, in which the surface materials are very thick, ranging from 400 to more than 1000 feet, the average being probably about 600 feet. This has been, and will continue to be a most effective obstacle in discouraging explorations for oil and gas.

BEDROCK GEOLOGY.

The rock strata of this part of the State compose the northern segment of the Michigan Basin, consequently in passing around the lake shore from Frankfort, Benzie county, to Harrisville, Alcona county, the strata dip successively southeast, south, and southwest toward the center of the Basin. The formations beneath the drift form belts more or less concentric with the lake shore, and in passing from the lake margin to the central basin the edges of the Devonian formations—the Dundee, Traverse, Antrim, Berea, Coldwater, Marshall, the Grand Rapids Group, and the Saginaw Coal Measures are crossed in order.

Relations of surface signs to the oil and gas formations. Three of the oil horizons outcrop at the surface or lie beneath the drift cover in this part of the State. Locally as in southeastern Alcona county there are springs which, from the amount of gas given off, appear to be in a state of ebullition and one of these near Killmaster (center of sec. 26, T. 26 N., R. 8 E.) gave off so much gas that it led to the Killmaster drillings (see Fig. 18). Similar springs occur near Atlanta, Montmorency county. Gas is struck in wells also, as in Benzie county and around Portage Lake, Manistee county.

In the vicinity of Alpena there is a large area in which the Traverse formation and the Dundee limestone outcrop, or are under a light cover of surface materials. The Traverse has been carefully studied in northern Michigan by Grabau, and the outcrops around Little Traverse Bay and Alpena have received very careful study from limestone, cement, and chemical companies, which have extensively developed the deposits of the high grade limestones of the Traverse and the Dundee formations.

While no prominent anticlinal folds are known to exist in Alpena county, discordant and abnormal dips, noted by Winchell and Rominger, occur in several localities. The general dip is to the southwest, yet the rocks north and east of Alpena dip northeast toward Lake Huron. The Dundee limestone is much fractured and faulted locally and extreme brecciation is characteristic of the Monroe Beds throughout the northern and southeastern part of the State.

During the past few years Mr. Henry R. Hindshaw, former assistant State geologist of New York, has made an extensive study of the limestone deposits of possible commercial value in Alpena and Presque Isle counties. He observed the abnormal dips, local fractures, and the brecciation of the Dundee limestone, which near Rogers City, is so great that drilling with a core drill is very difficult.

In the Salina, in Alpena and Presque Isle counties, the salt beds aggregate 300 to 800 feet in thickness. According to the upward rise of this formation toward the northeast and east, it should form the bottom of the Lake Huron basin. Thin salt beds occur at Manistee and Ludington, and here too are to be observed abnormal local dips and a "vesicular" dolomite above the salt which caves in drillings and is very probably brecciated. The brecciation in the Dundee and the Monroe in the Frankfort well appears to be undoubted.

In limestone areas, much of the drainage is underground. In the limestone belt of northern Michigan there are relatively few streams as most of the surface waters drain into the numerous sinks. The Dundee, especially near its base, and the Monroe beds are very heavily water bearing, being filled with crevices, fissures, caverns, and underground water channels. The water channel struck in the Detroit salt shaft was more than five feet across. In many instances drill tools suddenly drop four or five feet into cavities. Again, in drillings, beds of dolomitic sand are struck in the Monroe which flow into the drill holes like thin mud. Such sands and oozes may be the residuum of other beds carried away by solution.

Mr. Hinshaw related these facts—the abnormal dips, the brecciation of the Dundee and the Monroe beds, the large underground water

circulation, the oozes, the relation of the margin of the Salina formation to the basins of lakes Huron and Michigan, and conceived the idea that these lake depressions are due in part to the ablation, or solution of the salt in the Salina and that the brecciation was caused by the slumping incident to the removal of the salt beds below. While the validity of all of the evidence has not been investigated, the theory as advanced contains elements of plausibility and is worth consideration.

It is obvious that if the salt in the outer edges of the formation should be removed by solution, there would be slumping in the beds above, which might very possibly cause brecciation in rocks like dolomites and limestones. The slumping would also explain the abnormal dips, observed near the lake shores.

According to Mr. Hindshaw's theory, marked disturbances in the rock strata are liable to be found along the margin of the southern Peninsula, excepting in those regions where salt was never deposited. Such disturbances are favorable to the accumulation of oil and gas, but the brecciated rock must be capped by some soft and plastic stratum such as shale, which would not readily fracture or these products would escape.

LITTLE TRAVERSE BAY ANTICLINE.

Along the south shore of Little Traverse Bay, the limestones and shales of the Traverse formation outcrop in low bluffs. In the vicinity of Khagashewing Point (Fig. 2) there are numbers of low folds which pitch southward. While the folds are small, together they make up a structure sufficiently large to contain oil and gas in commercial quantity. A Mr. W. N. Norton, representing an eastern oil company, made a survey of the Charlevoix region and made preparation to drill a number of test wells in 1913, but for some reason the project was suddenly abandoned.

BENZIE COUNTY.

Frankfort. At Frankfort two wells respectively 1800 and 2200 feet in depth were drilled many years ago, but only a meager record of either was obtained. The first one, 1800 feet in depth, was abandoned on account of the great flow of water from the brecciated Dundee limestone at the bottom. The second is 500 feet to the southwest, and, at 1800 feet, a sulphate brine testing 20 per cent salinometer was encountered. This brine appears to come from a horizon corresponding to the Manistee and Stronach salt horizon. The well was continued to 2200 feet and the brine decreased in strength toward the bottom, where an enormous flow of water was struck, probably in the Niagara.

FRANKFORT WELL NO. 1.

A. G. Butler, owner? Reported by C. E. Wright and Mr. Percy. Vol. V, Pl. XVIII.

Elevation of mouth of well 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface.....	527	527
Traverse (Hamilton) Formation:		
Hard limestone.....	543	1070
Shale, soft caving stuff.....	160	1230
Dundee (Corniferous) limestone:		
Black to gray brecciated limestone with hard flinty blocks.....	150	1380
Bottom at.....		1800
Much water towards bottom, 8000 barrels per day.		

EMMET COUNTY.

Petoskey. At Petoskey, a well was drilled nearly if not quite to the bottom of the Dundee limestone. Judging from the depth of the drift the well is in an old glacial rock valley for within a short distance on either side rock is only 5 feet below the surface.

PETOSKEY WELL.

Loc.: Thirty-three feet north of Chi. & West. Mich. R. R. station near end of Lake Street and 180 feet from Bear river. Drilled in 1888. Reported by H. P. Parmelee, Charlevoix; C. S. Hampton, G. S. Richmond, Petoskey.

Elevation of well 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Gravel, etc.....	30	30
Traverse (Hamilton) Formation:		
Limestone strata, highly fossiliferous throughout the entire depth. The fauna is nearly the same as that found in the surface bed. Color light gray, a few strata quite dark and much harder.....	250	280
Ten to 15 ft. of blue shale, no fossils. Beneath this was a flow of quite pure water, somewhat charged with H ₂ S.....	15	295
A nearly solid bed of <i>Acervularia</i> limestone, without a trace of mollusca or other corals. Color light, often creamy white.....	60	355
A thin layer of gray lime rock of incoherent structure at 355.		
Bell shale (Marcellus):		
Dark shale.....	80	435
Dundee (Corniferous) limestone:		
About 120 ft. of crystalline limestone of same color, texture and composition throughout.....	120	555

Bay View. At Bay View, a well about 500 feet deep was drilled in 1895. This record and others show that the Traverse on the western side of the State is predominantly limestone, shale being very subordinate in quantity in contrast to the Alpena region. The only thick bed is the blue basal or Bell shale in which the drilling stopped, but thin shale beds have been struck in some of the shallow wells along the south shore of Little Traverse Bay.

A very hard layer was struck at 450 feet in which only 18 inches a day could be drilled. Water in great quantity was struck in the lime-

stone below this shell. Nearly all of the limestone is hard as an average of only 10-12 feet per day could be made.

BAY VIEW WELL.

Loc.: One hundred and twenty paces northwest from the door of G. R. & I. R. R. station and 40 feet from the shore of the bay. Reported by H. P. Parmelee, Charlevoix, and A. J. Richards. Completed July, 1895.

Elevation of well 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Shingle.....	4	4
Traverse:		
Cream limestone.....	260	264
Medium gray limestone.....	198	462
Dark limestone.....	11½	473½
Twenty-five feet of cellular blue shale.....	25	498½
Flow, 200 bbls. an hour.		

CHARLEVOIX COUNTY.

Charlevoix. In Charlevoix, three wells were drilled within 50 feet of each other. Only of No. 3 were samples obtained. The drift was found to be 230 feet in thickness, yet rock is at the surface to the east and west of the city. This indicates the presence of deep rock valley. Apparently the well was bottomed in the blue Bell shales at the base of the Traverse.

CHARLEVOIX WELL.

Elevation 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand.....	6	6
Gravel.....	9	15
Fine sand.....	155	170
Gravel.....	6	176
Sand; quicksand at 214 ft.....	54	230
Traverse:		
Fine grained earthy limestone, eff. with dilute HCl. No fossils found in the samples.....	10	240
Gray limestone, eff. freely with dilute HCl. No fossils in samples.....	10	250
Earthy or chalky, brownish, porous, much oxidized clayey limestone with a strong clay odor, being in fact in large part clay, but with sufficient lime to give it coherence, and cause free eff. with dilute HCl.....	10	260
Dark gray argillaceous and somewhat shaly limestone, eff. freely in dilute HCl.....	10	270
Finely stratified shale, eff. feebly with strong HCl. Compact in texture.....	10	280
Fossiliferous whitish limestone, containing <i>Atrypa reticularis</i> and other fossils. Eff. freely with dilute HCl.....	10	290
White crystalline limestone containing considerable crystalline calcite. It carries fragments of <i>Acervularia davidsoni</i> . Some portions of the samples are compact and argillaceous.....	10	300
White chalky limestone, non-argillaceous, fossiliferous; eff. freely with dilute HCl.....	15	315
Brownish, earthy and argillaceous limestone, with a strong clay odor; Bryozoa and other fossils have been observed. Eff. freely with dilute HCl.....	7	322
Gray calcareous clay of very uniform texture, partially oxidized. Eff. freely in dilute HCl, but is nevertheless a good clay.....	8	330
Gray, compact calcareous clay rock, but of massive character, and eff. freely in dilute HCl.....	5	335
Fragments of <i>Acervularia davidsoni</i> with the calices free from matrix, and evidently embedded in clay. No clay is, however, retained.....	10	345
Gray calcareous shale, mixed with pure white limestone, the latter containing Favosites and Acervularia.....	5	350
Gray argillaceous limestone and some white limestone, with fragments of Spirifer and Acervularia.....	5	355
Gray limestone. <i>Acervularia davidsoni</i> is abundant. Favosites and <i>Atrypa reticularis</i> also occur.....	5	360
Gray, compact, semi-argillaceous limestone; fossils not observed, except crinoid stems. Much shale is mixed with the limestone.....	7	367
Fragments of <i>Acervularia davidsoni</i> and Favosites.....	3	370
Compact, gray, argillaceous limestone; no fossils observed. It is almost a clay.....	5	375
Fine grained, compact, argillaceous rock.....	12	387
Limestone and black shale.....	3	390
Gray argillaceous limestone with whiter limestone containing <i>Acervularia</i>	10	400
Chalky clay. Crumbles and soils fingers. Cream colored.....	2	402
Bluish gray clay, slightly calcareous; eff. feebly with HCl.....	8	410
Compact, brown to gray limestone, weathering earthy.....	5	415
Cream colored calcareous clay, identical with the rock at 400 ft.....	5	420
Limestone similar to that at 410 ft. No fossils.....	10	430
Cream colored earthy clay, somewhat more calcareous than that at 402 ft.....	13	443
Brown banded limestone, mingles with black and gray shale containing <i>Atrypa reticularis</i> , etc.....	4	447
Bell Shale:		
Bluish clay, non-eff.....	13	460
Same as preceding.....	22	482

Apparently in none of these wells were there any showings of oil and gas worthy of record, but the Petoskey well is the only one which penetrated the Dundee oil horizon.

The wells are so shallow that they do not reach horizons which outcrop on the northern shore of Lake Michigan. To the south the Grayling well is the only one of accurate record with which comparisons can be made, but this well apparently did not reach the Dundee, hence accurate calculations of dip cannot be made. An approximation may be made, however, by assuming that the Traverse at Gray-

ling (1140 ft. A. T.) is not over 600 feet thick, in which case, the top of the Dundee should occur at about 2880 feet at the latter place. The base of the Traverse in the Petoskey well occurs at 435 feet. Allowing for the difference in elevation of the two places, the base of the Traverse at Grayling is probably about 1905 feet lower than at Petoskey, representing an average dip of over 38 feet per mile slightly east of south.

WEXFORD COUNTY.

Cadillac. In 1913 the Cadillac Oil & Gas Company, C. R. Smith, president, and Bruce Smith, secretary, was organized and in the winter of 1914 began drilling a test well on the C. R. Smith farm near Cadillac. According to reports the well was located by means of an "instrument" invented by T. H. Cross, who superintended the drilling.

Unfortunately the drift is very deep in the vicinity of Cadillac and considerable difficulty has been encountered in getting the drive pipe down. The upper 470 feet was entirely sand and gravel, and at last reports the well was still in drift at 712 feet. A good set of samples was preserved for the Survey from which the following partial record has been compiled.

CADILLAC OIL & GAS COMPANY WELL NO. 1.

Loc.: C. R. Smith farm, S. E. $\frac{1}{4}$, S. W. $\frac{1}{4}$ sec. 28, T. 22 N., R. 9 W. Theo. H. Cross, well superintendent. Record by R. A. Smith from samples.

	Thick- ness, feet.	Depth, feet.
Pleistocene drift:		
Yellow sand with small pebbles. Yellow color due to oxidation of iron minerals.....	20	20
Fine light yellow sand.....	80	100
Gravel with pebbles of chert and limestone predominating.....	9	109
Fine yellowish clayey sand.....	15	124
Coarse gravel with much white chert and some pebbles of crystalline rocks.....	13	137
Fine yellowish sand.....	58	195
Gravel with white chert pebbles, some of fossiliferous limestone, black and white sandstone. Very few pebbles of crystalline rocks.....	10	205
Fine yellowish clayey sand.....	82	287
White sand, and small pebbles of chert, magnetite, red jasper and green schist.....	143	430
Slightly finer yellowish clayey sand.....	40	470
Clay, highly calcareous with considerable white sand (probably from overlying bed). Clay brownish in natural sample, white when pulverized; vigorous eff. with cold dilute hydrochloric acid.		
Well in drift at 712 feet, according to reports.		

CHEBOYGAN COUNTY.

Cheboygan. About 1900, one of the deepest wells in the Southern Peninsula was drilled at Cheboygan for rock salt. Rock outcrops to the west of Cheboygan, and on the adjacent islands, but the drift was found to be 380 feet in depth, indicating the presence of a deep pre-glacial rock valley. The first rock encountered was the Monroe in-

stead of the Dundee as would have been the case if the latter had not been removed by erosion in the formation of the rock valley.

The well, 2750 feet in depth, was bottomed in dark drab shaly dolomite probably near the base of the Lorraine (Hudson river) shales, and did not reach the Utica or the Trenton.

CHEBOYGAN WELL.

Loc.: At Swifts and Denks (?) near corner Blair and Turner streets. Samples examined by W. C. Alden, U. S. Geological Survey. (See Ann. Rept. for 1908, p. 96).

Elevation of well 600? ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Red clay, highly calcareous	150	150
Sand and gravel	53	203
Sand	2	205
Sand, gravel and red clay	25	230
Gravel	15	245
Sand with some calcareous material	5	250
Sand and gravel	5	255
Gravel	15	270
Fine sand with calcareous material	30	300
Gravel	34	334
Gravel, coarse	18	352
Fine sand with calcareous material	2	354
Fine sand with calcareous material, coarser	6	360
Fine sand with calcareous material, fine	15	375
Much water in drift.		
Fine calcareous sandy clay	5	380
Second box of samples.		
Light to whitish dolomitic limestone at 265 ft.		
Chips of dark grayish dolomite with some quartz sand grains from 265-278.		
Light colored limestone at 300 ft.		
Grayish, dark, porous, earthy dolomitic limestone at 320 ft.		
Monroe (Upper Silurian, Water Lime and Salina).		
Fine chips of brownish buff gray dolomite with a little chert at 380-438 feet.		
Red shaly stuff from 850 to 900 ft.; red sandy shale at 1000 ft.		
Flows of water at 1050, 1350 and 1400 ft.		
Brecciated dolomites with slits and cavities.		
Caved down to 750 ft.		
Salt (March 12, 1901), at ? 1400 ft.		
Fine grayish sand and dolomitic materials with some white chert and bluish and reddish shaly material at 1360?-1550 ft.		
Niagara:		
Beginning of Niagara (Guelph)	?	1550
Fine quartz sand, slightly calcareous	?	1615
Fine quartz sand, slightly calcareous, brownish	?	1625
Fine quartz sand, slightly calcareous, brownish	?	1635
Light grayish crystalline dolomite	?	1652
Light grayish crystalline dolomite	?	1725
Buff fine angular grains of quartz, chert with some dolomitic material ..	?	1975
Dark gray, very cherty dolomitic material	?	2000
Fine, angular, gray dolomitic material	?	2050
Fine, angular, gray dolomitic material. Lockport about here—2065 ft. ..	?	2100
Fine, angular, gray dolomitic material; Rochester shale 2136-2200 ft.	?	2150
Fine, angular, gray dolomitic material	?	2175
Fine, angular, gray dolomitic material. Dark colored, nearly black	?	2200
Clinton:		
Fine, angular, gray dolomitic material. Lighter colored	?	2225
Fine, angular, gray dolomitic material. Lighter colored. Contains small particles of iron or magnetite	?	2250
Medina (See Lorraine below):		
Dark purplish ferruginous material, reddish streak, in small flattened, rounded lenticular pellets. With this is some bluish shaly material, moderately calcareous. Some particles rounded. Also few quartz grains. Bluish shaly material increases in lower samples.	125	2425
Lorraine. Lower part:		
Dark drab shale, or dolomite, somewhat calcareous. Small particles of iron or magnetite	125	2425
Dark drab shale, or dolomite, somewhat calcareous. Small particles of iron or magnetite	300	2725
Utica at		2750

CRAWFORD COUNTY.

Grayling. In 1901, R. Hanson of Salling, Hanson & Co. drilled three wells at Grayling and one, the No. 3, reached a depth of 2800 feet. This well, though one of the deepest in the State, was drilled very quickly. Work began the last of January and, by May 6, the well was finished at a depth of 2800 feet. This well penetrated about 520 feet of Traverse limestones and shales, but did not reach the heavy shale (Bell or Marcellus) at the base of the formation.

GRAYLING WELL NO. 3.

Salling, Hanson & Co., owners, Grayling. T. Percy, driller. Drilled in 1901. Samples, records from notes of A. C. Lane and F. W. Cooper.

Elevation of well 1140 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	50	50
Till or boulder clay.....	50	100
Mainly sand, some clay and gravel, plenty of water. Progress slow through water bearing quicksand.....	200	300
Sandy clay till.....	25	325
Coarse cement sand, etc.....	25	350
Michigan Series:		
Dark shale.....	30	380
Blue or bluish shale and gypsum.....	30	410
Dark blue shale.....	30	440
Upper Marshall or Napoleon:		
White sandstone, micaceous toward the bottom.....	100	540
Lower Marshall and Coldwater:		
Blue shale.....	90	730
Brownish and probably sideritic (iron carbonate nodule) at 720 ft. Dark blue shale.....	650	1380
Compact blue shale.....	220	1600
Berea horizon?		
Apparently not recognized.		
Antrim shale:		
Black shale.....	20	1620
Blue shale.....	20	1640
Black shale.....	60	1700
Dark blue shale.....	60	1760
No sample at 1740 ft. nor none from 1780 to 1880.....	120	1880
Light blue shale.....	80	2060
Black shale.....	60	2120
Dark gray shale.....	20	2140
Black shale.....	40	2180
Gray shale.....	20	2200
No sample at 2200 ft. Black shale.....	20?	2240
Brown shale.....	40	2280
Pyritic from 2240-2280 ft.		
Traverse (Hamilton) formation:		
Light blue shale.....	20	2300
No sample at 2320 ft. Probably shale.		
Fossiliferous light blue shale and limestone.....	20?	2340
"Salt and pepper" limestone and shale.....	40	2380
Light and dark limestone.....	20	2400
Steel gray limestone.....	20	2420
Light colored limestone.....	20	2440
"Salt and pepper" limestone.....	20	2460
Light colored limestone and blue shale.....	20	2480
Light colored limestone.....	100	2580
Dark limestone, fine grained.....	20	2600
Steel gray fine grained limestone.....	20	2620
Light colored fine grained limestone.....	80	2700
Steel gray fine grained limestone.....	40	2740
Dark steel gray fine grained limestone.....	20	2760
"Salt and pepper" fine grained limestone.....	40	2800
Bell shales should occur just below 2800 ft. and the top of the Dundee at about 2880 ft.		

ROSCOMMON COUNTY.

Roscommon. Many years ago a drilling was made for oil near Roscommon, but statements concerning it are so contradictory that nothing very definite can be asserted. It is not known that the well reached bed rock before it was abandoned, but it appears that the drift is at least 365 feet thick, and is mainly sand with some clay at 118 and 365 feet. Mr. Fred Johnson of Roscommon is authority for saying that he and others saw oil at the well, which was claimed to come from it. Many consider that the well was "salted" and a fraud. One morning the well was found to have been filled with scrap and railroad iron, and the enterprise was abandoned.

PRESQUE ISLE COUNTY.

Onaway. In 1913 the Presque Isle Development Company was organized, H. T. Moeller of Detroit, president, and Judge W. H. Martin of Saginaw, secretary. Drilling was started with the intention of penetrating the Trenton unless oil or gas should be struck before reaching that horizon. The well was bottomed in the Niagara at a depth of 3106 feet without encountering any noteworthy signs of either oil or gas.

The Monroe beds and the Salina show a remarkable development, the former being nearly 1150 feet in thickness and the latter, 1175 feet, including about 800 feet of rock salt. The combined thickness is several hundred feet greater than any thickness previously known in Michigan or Ontario. The upper portion of the Monroe appears to be composed largely of limestone or dolomitic limestone instead of dolomite and for 200 feet below the middle of the formation, the dolomite is very cherty and somewhat sandy. Most of the salt is red or tinged with red. The first salt bed, 145 feet thick, varies in color from a reddish pink to a deep brick red and the 150 foot bed below 1950 feet is also red, but the 225 foot bed at the bottom is nearly all white or gray salt. Below the salt beds there are 281 feet of hard white and gray limestone.

Notwithstanding the fact that shale everywhere overlies the Trenton limestone and that none had been penetrated in this well below the salt beds, the drillers, according to statements of the officials of the company, pronounced these limestones of Trenton age and barren of oil or gas. Upon this supposition, the well was abandoned.

The hard white limestones below the salt beds probably belong in part to the Salina, but, if they are considered as wholly Niagara and this formation has its normal thickness of 600 feet for the northern part of the State, there is still about 300 feet of Niagara limestone to be penetrated before reaching the top of the shale series which

lies between the Niagara and the Trenton. This shale series in a descending order includes the Rochester, Clinton (generally dolomitic), Medina, Richmond, Lorraine and Utica and, while no close approximations can be made of the thickness of each of these formations, the total thickness is probably between 600 and 700 feet. From this it would appear that the bottom of the well is from 900 to 1000 feet above the top of the Trenton.

The company very kindly furnished the Michigan Geological Survey with a log of the well and a set of samples from which the following record has been compiled:

PRESQUE ISLE DEVELOPMENT COMPANY WELL.

Loc.: S. E. $\frac{1}{4}$, N. W. $\frac{1}{4}$, Sec. 5, T. 34 N., R. 2 E., on Merrit Chandler property, 40 rods W.-N. W. from Detroit and Mackinac railroad station at Onaway. Contractors, Schrier and Kerr, Lancaster, Ohio. Well started July 14th and finished November 14, 1913. Record by R. A. Smith from driller's notes and log and from samples.

Elevation 830 = ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene of glacial drift:		
Pink calcareous clay	10	10
Traverse (Hamilton) formation:		
Gray limestone; moderate eff.	15	25
Buff and dark gray limestone, and very argillaceous limestone; viol. eff. with strong smell of petroleum. Dark brown oily scum	100	125
Gray granular limestone; bituminous; fossiliferous, crinoids and corals; Viol. eff.; much white calcite.	15	140
Soft calcareous gray shale	10	150
Gray limestone with much disseminated calcite; fossiliferous (corals); vigorous eff.	20	170
Dark limestone; highly calcareous black shale; disseminated calcite.	80	250
Gray, brown and black shale, slightly calcareous	60	310
Dundee (Corniferous) limestone:		
Light buff, brown and black limestone, with much white calcite; vigorous eff. Limestone mottled and streaked	165	475
Reddish buff and light gray limestone. Buff violently eff. Red apparently an oxidized zone. Crevice from 480 to 510 feet. Water	35	510
Upper Monroe, Detroit River series:		
Hard, light buff limestone with rusty spots (from pyrite?); violent eff.; crevice at 525 feet.	15	525
Dark gray and buff limestone; pyritic; vigorous eff.	50	575
Gray to brown bituminous limestone; oily scum; violent eff.	50	625
Mainly buff limestone; violent eff.	25	650
White friable marl and fine grained light colored limestones; violent eff. No sample at 675 feet. Crevice from 655 to 700 feet; more water	50	700
Very hard white to light buff limestone, vigorous eff.	25	725
Very hard white and brown limestone; vigorous eff. Crevice at 750. No drillings obtained from 740 feet.	40	765
White limestone and dolomite; cherty; some fragments eff. vigorously, others slowly	15	780
White limestone, cherty, some gray and brown limestone, vigorous eff.	45	825
White and black limestone; vigorous eff.	30	855
Mainly black limestone, some white; bituminous oily scum; vigorous eff.	5	860
Brown to dark brown limestone, some white limestone and chert; vigorous eff. "20 feet of black limestone"	15	885
Grayish brown limestone; vigorous eff.	15	900
Grayish buff limestone; cherty; vig. eff.	25	925
White to buff gray limestone and dolomite; some particles eff. vigorously, others slowly	25	950
White to gray limestone; vigorous eff.	50	1000
Argillaceous marl and gray limestone; vigorous eff.	25	1025
White and buff gray limestone—"salt and pepper"; cherty; vigorous eff. Much water above 1050 ft. rose to within 160 ft. of surface; could lower head	25	1050
Sylvania? (Middle Monroe):		
White limestone, very cherty; vigorous eff.	50	1100
White limestone; vigorous eff.	25	1125
Extremely hard white and very cherty limestone, medium eff.	100	1225
Marl and dolomitic limestone; medium eff.	25	1250
Water (brine) not shut off.		
Hard white sandy limestone; vigorous eff.	50	1300

PRESQUE ISLE DEVELOPMENT COMPANY WELL.—Concluded.

Elevation 830 = ft. A. T.	Thick- ness, feet.	Depth, feet.
Lower Monroe: Bass Island series:		
Hard reddish brown limestone; very ferruginous; very red at 1375 ft.; vigorous eff.	50	1350
Very hard cherty gray dolomite; slow eff.	25	1375
Hard gray dolomite, with rusty spots either from pyrite or from particles of the drill. Selenite crystals, slow eff. More or less anhydrite down to the salt.	25	1400
Hard gray dolomite; slow eff.	25	1425
Light buff and gray dolomite; slow eff.	125	1550
Red shale and dolomite; slow eff.	15	1565
Gray dolomite; slow eff.	15	1580
Brown dolomite; slow eff.	50	1630
Cased to 1640 feet.		
Salina:		
Reddish salt.	145	1775
Red shale.	30	1805
White salt.	25	1830
Light shale and anhydrite.	100	1930
Reddish salt.	150	2080
Hard shale.	10	2090
Reddish salt.	65	2145
White salt.	25	2170
Buff shale.	10	2180
Gray salt.	15	2195
Dolomite.	15	2210
White salt.	35	2245
Pink to very red salt.	75	2320
Mainly anhydrite; some shale.	10	2330
Mainly salt, some dolomite.	15	2345
Dolomite and anhydrite.	75	2420
Salt.	50	2470
Anhydrite, dolomite and salt.	10	2480
Soft red shale.	15	2495
Dolomite and anhydrite.	25	2520
Mainly anhydrite.	25	2545
Salt and anhydrite.	15	2560
Gray dolomite and anhydrite.	10	2570
White salt; "caving at 2625 and at 2740; have to drill three screws to two of hole".	225	2795
Driller's record. No samples below 2825 ft.		
Gray limestone. 6 5-8 in. casing; no water.	15	2810
Brown limestone, very hard; 25 ft. per day.	40	2850
Hard gray or white limestone; 10 to 15 ft. per day.	226	3076

In the Onaway well, the base of the Traverse is 310 feet below the surface and in the Grayling well it is over 2800 feet as the Bell shale at the base of the formation was not penetrated. Since the Traverse is about 600 feet thick in the northern part of the Lower Peninsula, and as the Grayling well penetrated 520 feet of Traverse limestones and shales, the base of this formation in the Grayling well should occur at 2880 feet. The exact elevation of the mouth of the Onaway well is not known but it is about 830 feet above sea level. Allowing for the difference in elevation between Onaway and Grayling (1140 ft. A. T.), the base of the Traverse at the latter place is about 2250 feet lower than at Onaway. The distance from Onaway to Grayling is about 54 miles by map measurement, therefore the average dip south-southwest is nearly 42 feet per mile.

Grand Lake. A number of years ago, a well 1712 feet in depth was drilled by the Alpena Land Co. at Grand Lake. A careful record was

kept and a set of samples preserved. This well was started directly in the Bell shales at the base of the Traverse and penetrated the Salina 425 feet, passing through salt beds aggregating more than 300 feet in thickness. Strong flows of salt water were struck at 1000 and 1257 feet. Fresh water was probably struck in the Dundee and Upper Monroe, though not mentioned in the record.

ALPENA LAND COMPANY WELL NO. 1.

Loc.: About 14 miles north of Alpena at Grand Lake. Lot 1, Sec. 8, T. 34 N., R. 8 E.

	Thick- ness, feet.	Depth, feet.
Traverse:		
Bell shale.....	50	50
Dundee:		
Crinoidal and fossiliferous limestone, bituminous and pyritic.....	215	265
Upper Monroe:		
Mixed samples of dolomite and limestone.....	30	295
Lucas:		
Stylolitic limestone.....	15	310
Amherstburg:		
Blue and buff dolomite.....	70	380
Anderdon limestone:		
Brown limestone.....	55	435
Dolomite and lime.....	15	450
Limestone.....	85	535
Black shale mixing with sample below, and limestone. (Cf. Milan 820)	80	615
Flat Rock?:		
Limestone, crinoidal in many places.....	85	700
Sylvania horizon. Cf. Milan 845-890:		
Cherty, crinoidal limestone.....	100	800
Largely chert.....	30	830
Cherty limestone.....	170	1000
Lower Monroe:		
Gashed dolomite and limestone.....	20	1020
Limestone, sometimes deep brown (dolomite also).....	85	1105
Bluish dolomite, often gashed, with a few grains of sand.....	25	1130
Limestone, with a little sand, brown at top, then yellow. Water at 1257 feet.....	130	1260
Dolomite, Cf. Carmen 1210.....	24	1284
Top of salt formation or Salina, just about 450 feet below the cherty crinoidal limestone horizon that cannot be far from the Sylvania horizon. Compare Goderich groups IV and V.		
Salina:		
Salt.....	6	1290
Brown dolomite.....	50	1340
Salt and dolomite.....	7	1347
Hard layer.....	5	1352
Dark salt.....	5	1357
Salt, very clear from 1360-1395.....	80	1437
Anhydrite.....	28	1465
Reddish sand, marl or anhydrite.....	5	1470
Salt (top eight feet reddish).....	40	1510
Salt and anhydrite?.....	4	1514
Brown salt.....	14	1528
Salt and shale.....	5	1533
Dolomite, anhydrite and shale.....	19	1552
Salt and anhydrite.....	20	1572
Salt, clear.....	17	1589
Impure salt with shale and anhydrite.....	5	1594
Salt, mainly clean, white.....	57	1651
Salt with clay and anhydrite streaks at 1655-1678. Cf. Carmen well 2103.....	50	1701
Anhydrite and dolomite.....	11	1712

ALPENA COUNTY.

Alpena. The early borings at Alpena were drilled for salt. One of the deep holes was drilled about 1872 near the bed of Thunder Bay river and "salt," probably brine, was reported at about 1025 feet. The record shows 400 feet of Traverse limestone followed by 80 feet

of blue fossiliferous Bell shales. Beneath the shales is 120 feet of Dundee limestone variable in color and hardness. Below the depth of 600 feet are light colored dolomitic limestones.

Later, the Churchill well was drilled in Alpena close to the bay. A very careful record was obtained and a summary of the same is appended below. The top of the well is in the Alpena coral limestone of the middle Traverse, hence there are about 130 feet of Upper Traverse shales and limestones unrepresented in the record. Down to 444 feet there is a continuous succession of hard limestones and blue or calcareous shales. The hard and cherty Dundee limestone appears to be 99 feet thick, but perhaps the shale, and heavy limestone just below should be included with the Dundee. Farther north near Rogers City, Mr. Hindshaw reports the Dundee as being 215 feet thick. The Monroe beds down to 777 feet are alternations of relatively thin shale beds and heavy beds of hard limestone. Following this series is 480 feet of hard white limestone (dolomite).

The first flow of water in the rock was struck at 427 feet and a strong flow in the Dundee at 489 feet, which kept increasing down to 590 feet. This last flow was exceptionally strong. Other flows occurred at 605 feet and apparently at various intervals down to about 1050 feet. No oil or gas was encountered worthy of mention.

CHURCHILL WELL.

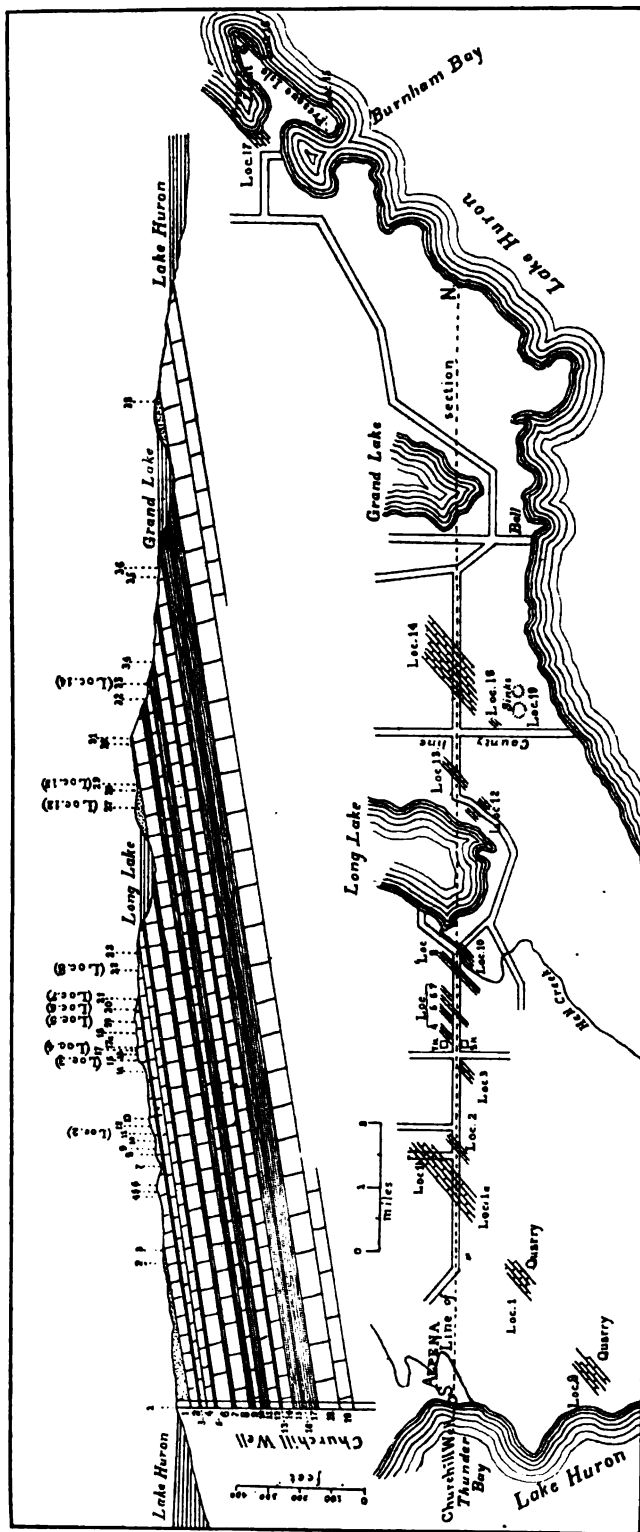
Elevation of well 585 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sand and boulders.....	41	41
Traverse:		
Hard white (light colored) limestone.....	25	66
Shale.....	9	75
Very hard white limestone.....	49.5	124.5
Shale.....	2.5	127
Extra hard gray limestone.....	40	167
Blue shale.....	20	187
Hard white limestone.....	34	221
Shale, 7 ft. white and slimy, possibly gypsum (?).....	18	239
Hard white limestone.....	23	262
Very sticky blue shale.....	27	289
Hard white limestone.....	32	321
Shale.....	3	324
Hard white limestone, upper two-thirds extra hard.....	39	363
Bell:		
Shale.....	24	387
Hard white limestone.....	5	392
Shale, mostly blue. Some water at 427 feet.....	52	444
Dundee:		
Hard white and gray limestone, mostly extra hard. Strong flow of water at 489 feet.....	60	504
Extremely hard (flinty) limestone.....	39	543
Monroe:		
Shale.....	25	568
Hard gray and white limestone (Dundee?) Great flow of fresh water at 590 feet. Vein of sulphur water at 605 feet.....	103	671
Shale.....	20	691
Hard white limestone water.....	86	777
Sandy lime and shale.....	10	787
Hard white limestone.....	480	1267
Salina:		
Rock salt.....	20	1287

There are several other wells in the city or near it, but they only penetrate the Dundee for fresh water. Among these are C. Moench & Sons, the Tannery, and the Fletcher wells. (Ann. Rept. 1901, pp. 172-73).

Local structures. The Grand Lake well is slightly west of north of the Churchill well at a distance of a little over 14 miles. The elevation of the former well is not given but from the indicated location it appears to be about 630 feet A. T. or higher than the Churchill well which is near the level (580 ft. A. T.) of Lake Huron. If this elevation is used in the calculations of dip the error probably will not be greater than a foot per mile. Since the Bell shales in the Grand Lake well are 50 feet thick, the top of the Dundee would come at the same level as the mouth (585 ft. A. T.) of the Churchill well in which the Dundee was struck at 444 feet. This figure therefore represents the amount of dip in 14 miles, or an average dip of nearly 32 feet per mile a little east of south. This agrees fairly well with Grabau's determination, which is about 30 feet per mile. As the strike of the rocks is northwest-southeast and the above dip is along a line (see fig. 17), very oblique to the strike the above figure does not represent the maximum dip, which should be to the southwest. The 30 to 32 foot dip along the line from Grand Lake to Alpena should be equal to about 42 feet per mile to the southwest, and Grabau found that the average local dip, determined in several places, is approximately this figure.

Along the lake shore, however, northeast of Alpena, N. H. Winchell in 1870 noted marked dips toward the lake, yet at some distance from the shore he observed, in almost the opposite direction, a dip of 10° to the southwest. In the case of the Traverse beds, however, such dips may be due to the presence of the coral reefs, the dips being away from the reefs. Others have noted the same discordant dips. As noted on previous pages Mr. Wm. L. Hindshaw reports the same lakeward dips near Rogers City and associates them with the slumping of the formations due the ablation of the underlying salt beds along the margin of the lake.

The distance from the Grand Lake well to Grayling, according to map measurement, is about 74 miles. Comparing the wells at these two places, the latter being about 510 feet higher, the average dip appears to be about 32 feet per mile. As Grayling is not in direct line with the center of the Basin, and apparently is to the west of the north-south median line, this figure must be less than the maximum dip, i. e., 42 feet. As will be seen later, the dip southward from Part-ridge Point, Alpena county, where the Antrim shale outcrops, to the Killmaster wells in Alcona county is approximately 35 feet per mile,



and this should be equal to about 50 feet per mile to the southwest. From the foregoing approximations, it seems that the average southwest dip in the northeastern part of the Southern peninsula is between 40 and 50 feet per mile, 42 feet being about the average for the Alpena district.

While the Antrim, Dundee, and Traverse formations are bituminous, or contain bituminous horizons, yield a strong petroleum odor, and small quantities of gas in the northeastern part of the Southern Peninsula drillings have not shown any very promising signs of oil.

ALCONA COUNTY.

Relation of the rock formations to surface signs. Alcona county is underlain by the Marshall sandstone which crosses the southwestern corner, the Coldwater shales, the Berea sandstone, and Antrim black shale, the latter crossing the northeastern corner of the county. The strike of the formations is approximately northwest-southeast, therefore the dip is southwest toward the central part of the Basin. No rock outcrops are known in Alcona county. The Berea underlies the drift at Harrisville, as shown by the well at that place, and extends northwest toward Atlanta in Montmorency county and Vanderbilt in Otsego county. It is along the strike of this horizon and the Sunbury black shales that surface signs are most abundant.

There is another source of gas, however, and this is in the drift itself which contains an abundance of bituminous shale fragments, evidently from the Antrim. Apparently this bituminous material yields small but appreciable quantities of gas which collect in gravel beds in the drift.

In Alcona county, there are a large number of springs, some of which yield gas in considerable quantities. One of these near the center of sec. 26, T. 26 N., R. 8 E., yields so much gas that it led to the Killmaster drillings. According to reports, the gas from this spring when lighted will blaze up two or three feet above the water. There are several other similar gas springs in the same township as on secs. 14 (2 springs), 32, and 34. Gas springs also occur in sec. 15, (2 springs) T. 25 N., R. 8 E., and along the bed of the east branch of Pine river. Oil has also been noted on the Angus Cameron farm, sec. 12, T. 28 N., R. 5 E., and gas was struck in gravel, just above bed rock in the No. 1 Killmaster well.

Most of the county is deeply drift covered and there are no rock outcrops even in the deepest river valleys. Practically all knowledge of the bed rock geology has been obtained from drill holes at Killmaster and Harrisville, and from wells in Alpena and Iosco counties.

Killmaster. Three wells were drilled at Killmaster. The No. 3 well, drilled in 1892, was the last and deepest (1530 feet). Some gas with a very small amount of oil was struck in the top of the Berea which yielded an abundance of brine lower down. The latter overcame the oil and gas, but according to reports some years ago the well was still yielding bubbles of gas. Below the Berea the hole was absolutely dry.

KILLMASTER WELL NO. 3.

Loc.: Five hundred paces N., 1000 paces W. of the south line of sec. 22, T. 26 N., R. 8 E. On the east side of the stream 10 rods from the bridge. No samples.

Elevation 670 = ft. A. T.	Thickness, feet.	Depth, feet.
Surface:		
Sand, then till, no gravel at the bottom.....	240	240
Coldwater Shale:		
Sandstone.....	4	244
Gray shale.....	6	250
Sandstone.....	4	254
Gray shale.....	275	530
Sunbury (Berea) Shale:		
Red shale.....	20	550
Black shale.....	20	570
Berea Grit:		
Sandstone: Gas in top of sandstone, and a very small quantity of oil, which was overcome by salt water in the sandstone below the gas. However, bubbles of burning gas (not H ₂ S or CO ₂) are now coming up continually in the water.....	40	610
Antrim Shale:		
Gray shales (compare Bedford shales).....	150	760
Dark shales (compare Cleveland shales).....	150	910
Gray shales (compare Erie shales).....	25	935
Dark shales (compare Huron shales).....	65	1000
(The top of the Traverse may be here.—Lane.)		
Gray shale and limestone.....	32	1032
Black shale (compare Huron shale).....	58	1090
Traverse (Hamilton) Formation:		
Hard limestone.....	8	1098
Soft limestone.....	80	1178
Hard limestone.....	90	1268
Hard limestone.....	4	1272
Soft limestone.....	20	1292
Limestone.....	238	1530
Color varies from light to dark from 1090 ft. down.		

The No. 1 well is about 80 rods from No. 3, a little east of south, and it is about 10 feet higher. It is only 600 feet deep and stopped in a hard bed supposed at the time to be limestone, but it appears that this is only the hard upper crust of the bed at 570 feet in the No. 3 well. The formations are similar to those in No. 3 well except that there is a bed of gravel just above the rock which served as a reservoir for gas. (See Fig. 18), with a pressure of 103 pounds. The gas, however, was afterwards overcome by a large flow of nearly fresh water from the sandstone below.

Harrisville—In 1904 a well 506 feet deep was bored at Harrisville at the courthouse striking the Berea sandstone directly under the drift (Fig. 19) at 230 feet. There were signs of oil in the drift at 100 feet, but no further signs of either oil or gas were observed at any other horizon in the well.

HARRISVILLE WELL.

Loc.: Court House, Harrisville.

Elevation of well 640 ft. A. T.	Thick- ness, feet.	Depth, feet.
Post Glacial and outwash:		
Yellow loamy soil.....	12½	12½
Quicksand.....	14	26½
Red clay.....	6½	33
Gravel.....	6	39
Glacial:		
Wisconsin. Last till sheet (sand of mixed character, boulders, etc.)....	60	99
Interglacial:		
Sand, signs of oil.....	30	129
(Quicksand, solidified to a blue hard pan at base).		
Earlier till sheet:		
Red hard pan.....	59	188
(Weathered till sheet).		
Red clay.....	4	192
Blue hard pan and pebbles.....	38	230
Berea Grit:		
White fine grained sandstone.....	30	260
Antrim shale:		
Light gray shale (Bedford) or weathered black shale.....	149	409
Brown and black shale.....	97	506

The Killmaster No. 3 well is about 8 miles west and $2\frac{1}{2}$ miles south from the Harrisville well, and allowing for the difference (30 feet) in altitude, the top of the Antrim in the former is 320 feet lower than in the latter. This represents a dip of 38.4 feet per mile in a direction a little south of west. This is exactly the same as the southward dip of the No. 2 well of the Alpena Business Men's Association at Partridge Point to the Killmaster wells. The direction of the maximum dip is probably between the two directions given above, or approximately southwest and would be about 42 feet per mile, or the same as the southwest dip in the vicinity of Alpena.

Comparing the Harrisville well with the James Norn well of Standish, Arenac county, the Berea appears to dip southwest at about 25 feet per mile. At Tawas City and Oscoda, a brine bearing sandstone occurs at 680 feet and 960 feet respectively. If the Tawas brine horizon is the Berea, then there is a pronounced syncline between Harrisville and Tawas and an anticline at the latter place. The sandstone at Tawas, however, appears to be above the base of the Coldwater, hence it corresponds to the Richmondville rather than the Berea sandstone.

Conclusions. The wells at Killmaster show that, locally, the Berea grit is not only a porous sandstone, but that it might contain gas and oil in commercial quantity if proper structural conditions were found. At Harrisville, however, the sandstone is too fine grained to be a free yielder and there was no showing of either oil or gas in the top of the Berea, although there is apparently an impervious cover of clay over

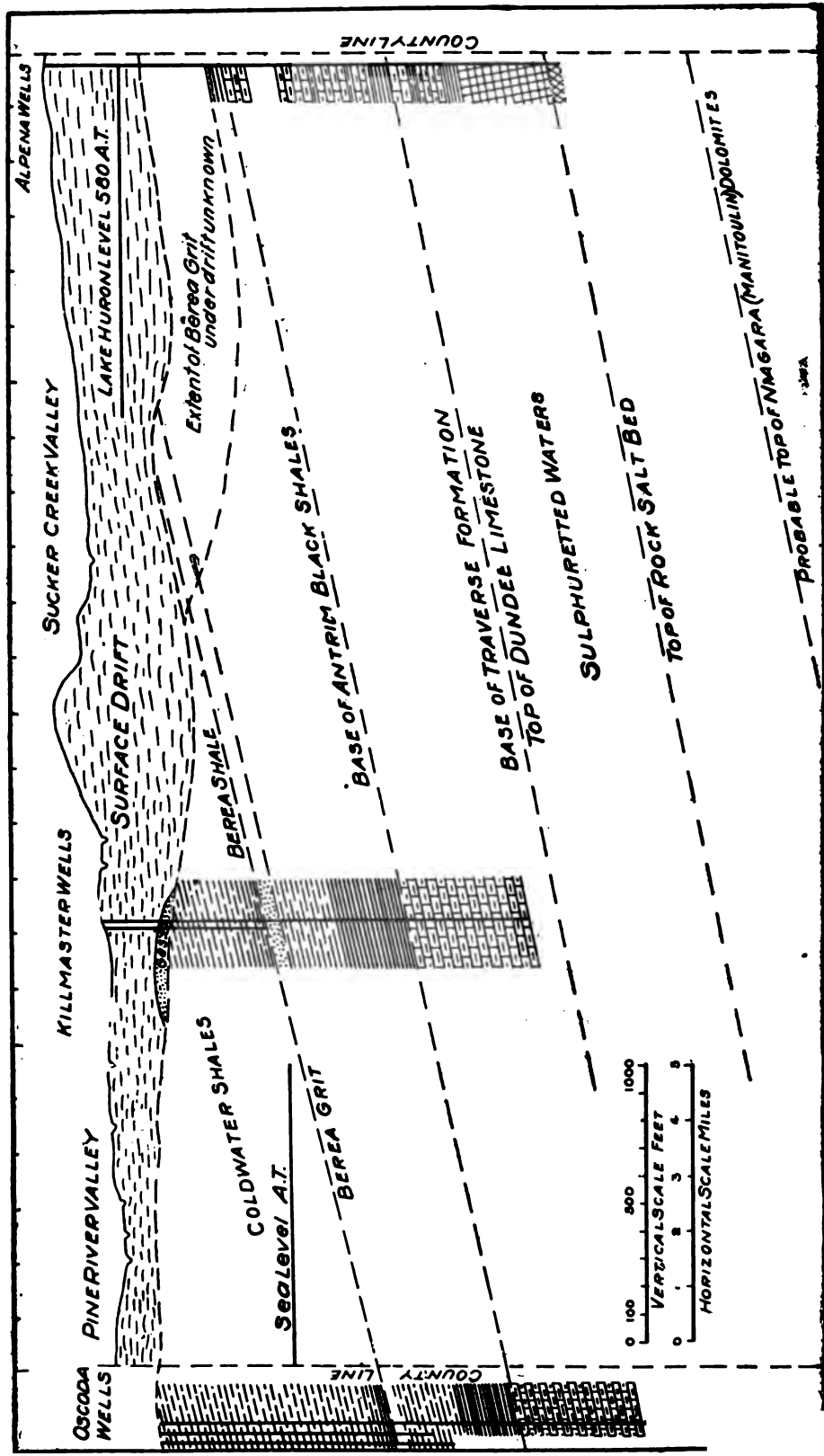


Figure 18. Geological section from Alpena south through Alpena county to Oscoda, Iosco county. (Annual report Mich. Geol. Surv., 1901, Plate II).

the outcrop (see Fig. 18) which ought to have trapped small quantities of oil and gas in the top of the sandstone itself. Elsewhere along the outcrop, these products probably escape into the sands and gravels of the overlying drift as illustrated in Fig. 19.

As the drift is very thick over most of the county, there are ample chances for the accumulation of considerable quantities of gas in the drift, especially along the strike of the Berea grit and the overlying and underlying black shales. Such accumulations are more apt to be found northwest from Harrisville toward Hubbard Lake, Atlanta in Montmorency county, and Vanderbilt, Otsego county. In order to test the possibilities of the Berea, explorations should be made at some distance to the southwest of this line of outcrop and belt of leakage.

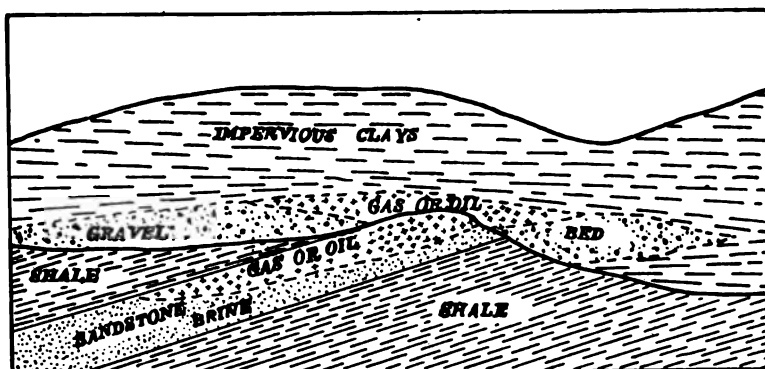


Figure 19. Diagrammatic sketch showing the possible occurrence of oil and gas along the strike of the Berea sandstone in Alcona county.

In Alcona county, the Traverse and Dundee formations are comparatively shallow and could be easily and cheaply tested. While the Traverse at Saginaw has three oil and gas bearing horizons, at Killmaster it was free from water and showed no signs of either oil or gas. The porosity of this formation, however, varies greatly in short distances and this is favorable for the occurrence of accumulations as in the so-called Saginaw sand in the Garey-Casamer No. 1 well at Saginaw:

Below the Traverse is the Dundee limestone which was not reached in the Killmaster drillings. Under favorable structural conditions oil may be found in considerable quantity in this formation, but the drillings are too few in Alcona county to indicate the presence or location of an anticline or structural bench, if either should exist. The oil and gas horizons beneath the Dundee, the Niagara, Clinton, Medina,

and Trenton are so deep that the cost of testing them would be out of proportion to any reasonable chance of success.

IOSCO AND OGEMAW COUNTIES.

AuSable and Oscoda Wells. In Iosco county at AuSable and Oscoda, eleven or more wells were put down by lumber companies for brines. The wells, all located within a radius of a mile, are in three groups which may be termed the Pack, the Smith, and the Loud. No detailed log of any of these wells is available, but from various sources the following information, which may be relied upon with a fair degree of confidence was compiled by Dr. A. C. Lane.

The Pack wells are from 20 to 25 feet above the lake, the Smith about 15 feet, and the Loud 6 to 8 feet. The drift, 90 to 100 feet thick, is mainly sand. The rock strata down to 200 feet, or more, are a series of sandstones and shales, apparently belonging to the Lower Marshall formation, which yields a very weak brine (one-half — one per cent of salt). Below the Marshall blue shales with an occasional red horizon predominate down to the Sunbury black shale which overlies the Berea grit. The latter in the Pack wells was struck at 950 feet, in the Smith at 960 feet, and probably at a little greater depth in the Loud. The brine of the Berea is strong (90°—98° salinometer test) and pure, but the sandstone is so fine grained and shaly that there is not a free flow.

According to Mr. E. E. Holmes, the sandstone runs out to the north, yielding less and less brine. This can be the condition only for a short distance, however, as the sandstone is well represented at Killmaster and Harrisville. At Grayling, Alma, Mt. Pleasant, and in other places in the central and western parts of the State, the formation appears to be represented by shales, generally red or sandy.

According to the records of wells in various parts of the State the Berea, while locally coarse grained and porous, yielding an abundant flow of brine, is apt to be very fine grained or shaly as at Oscoda, Harrisville, Bay City, and Saginaw. In such localities, it cannot be a free yielder of oil and gas.

One of the Pack wells was drilled to a depth of about 1800 feet, reports varying from 1760 to 1850 feet. Only blue and black shales with thin streaks of limestone were penetrated below the Berea, and no water or signs of oil and gas were encountered. It is almost certain that the well did not reach the Dundee, but the bottom must have been very close to the top of this formation for the drill stopped in black shale, quite possibly the Bell (Marcellus) at the base of the Traverse. The hardness, light color, and the mineral waters of the

Dundee would have been noted and remembered if the drill had reached this horizon.

At Harrisville the Berea is only 30 feet thick, being in part eroded. If it was originally as thick as it is at Killmaster, about 10 feet must have been removed, and the top of the Berea would have occurred at 220 feet instead of 230 feet. Using the first figure and allowing for the difference (35 ft.) in elevation of the mouths of the Harrisville and Oscoda wells, the Berea is approximately 765 feet lower at the latter place about $16\frac{1}{2}$ miles to the south. This is equal to a dip of over 46 feet per mile, or about 8 feet per mile more than from Part-ridge Point, Alpena county, to Harrisville, or from Harrisville west-southwest to Killmaster. Computing the dip to the south-southeast from Killmaster to Oscoda, it is found to be about 30 feet per mile. If the black (Bell) shale at the bottom of the Pack well is the same as that at the top of the Grand Lake well, the dip southward from Alpena to Oscoda must be between 30 and 40 feet per mile.

From the above, the general or maximum dip for eastern Alcona and Iosco counties appears to be nearer south than southwest. From Oscoda south to Caseville across Saginaw bay in Huron county and south-southwest to Bay City, there is a decided flattening of the dip of the Berea, as the dip is only about 22 feet per mile toward the former and less than 20 feet per mile toward Bay City.

Tawas City. Several drillings have been made by the lumber companies of Tawas City for brine, which was struck in a coarse white or gray sandstone, apparently in the Coldwater shale but at some distance above the true Berea horizon.

TAWAS CITY WELL.

Loc.: Grant & Sons Mill.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Sand.....	30	30
Clay, yellow.....	20	50
Napoleon or Upper Marshall:		
Sandstone, whitish.....	60	110
Lower Marshall and Coldwater:		
Sandstone, red.....	15	125
Sandstone, gray.....	5	130
Sandstone, red.....	40	170
Shale, light colored.....	10	180
Shale, arenaceous red.....	30	210
Shale, light colored.....	5	215
Shale, arenaceous red.....	88	303
Shale, blue.....	35	338
Sandstone, red.....	40	378
Shale, hard, light colored.....	60	438
Sandstone, red.....	5	443
Shale, white.....	15	458
Sandstone, red.....	5	463
Shale, hard, light colored.....	40	503
Sandstone, red.....	5	508
Shale, white.....	3	513
Shale, arenaceous, light colored.....	3	516
First indications of brine.		
Shale, white, hard.....	164	680
Richmondville?:		
Sandstone, gray.....	195	875
Abundant supply of strong brine.		
Appears to be too near the top of the Coldwater to be the Berea.		
Shale, blue.....	10	885

The general dip of the strata in Iosco county is apparently south-southwest at about 25 to 30 feet per mile. According to this the Berea should occur about 300 or 400 feet deeper at Tawas City than at Oscoda. Since the Berea is struck at approximately 950 feet in wells at the latter place it should be 1250 or 1350 feet below the surface at Tawas City. As the brine bearing sandstone at this place is struck at a depth of only 680 feet it appears that it is not the Berea but the Richmondville or some stray sandstone in the Coldwater shales 600 feet or more above the Berea horizon.

If the sandstone in question is the Berea proper, there is a very pronounced anticline in Iosco county with its crest near Tawas City.

OGEMAW COUNTY.

Prescott. In 1912 Mr. F. Jahncke of Alpena drilled a well for water near Prescott in southeastern Ogemaw county. The Upper Marshall was struck at 308 feet and the Coldwater shales were penetrated about 170 feet.

PRESCOTT WELL.

Loc.: S. W. Cor. of sec. 36, T. 22, R. 4 E., Ogemaw county. Franz Jahnce, contractor, Alpena, Mich., March 16, 1912. Record furnished by Mr. Jahnce, also samples.

Elevation of well about 768 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Red clay.....	6	6
Blue clay.....	9	15
Fine white sand.....	6	21
Red clay.....	37	58
Gravel.....	2	60
Red clay.....	55	115
Red clay and grit.....	14	129
Blue clay, round fragments of gypsum and rock.....	25	154
Michigan Series:		
Gray rock (Sample missing).....	4	158
Blue shale.....	27	185
Gypsum.....	4	189
Blue shale.....	1	192
Dark rock.....	3	195
Dark shale.....	3	198
Gray limestone.....	4	202
Blue shale.....	5	207
Dark rock.....	1	208
Gypsum.....	2	210
Dark blue limestone.....	10	220
Brown limestone.....	3	223
Gypsum.....	8	231
Blue shale calcareous.....	3	234
Blue limestone.....	4	238
Brown limestone.....	12	250
Gypsum.....	3	253
Blue limestone.....	9	262
Hard gray limestone.....	12	274
Chert (a little flow of water).....	2	276
Dark blue limestone.....	12	288
Blue shale and dark.....	18	306
Chert very hard.....	2	308
Upper Marshall or Napoleon:		
White sand (water rises from 26 ft. to 22 ft. 4 in. from top of casing)...	10	318
Chert (Sample missing).....	2	320
White sand.....	16	336
Red sand (Sample missing).....	3	339
White sand (Sample missing).....	21	360
Light blue sand.....	68	428
Water 16 ft. 7 in. from surface.		
Lower Marshall:		
Red rock with mica.....	55	483
Coldwater?		
Blue shale (Sample missing).....	45	528
Brown rock with mica.....	62	590
Blue shale sandy.....	44	634
Brown shale sandy.....	16	650

ARENAC COUNTY

Standish. In Arenac county, there are a number of wells penetrating rock, but they are shallow excepting a 1900 foot well drilled by James Norn at Standish of which no log was kept but it appears to have reached the Berea (Sunbury) black shale just above the Berea grit. Below the Marshall, blue shales of the Coldwater which yielded a little brine, predominated.

The record given below has been largely compiled from notes and statements of persons connected with the drilling of the well, and may be taken as fairly representative of the general character and thickness of the formations penetrated.

JAMES NORN WELL.

Loc.: Standish.

Elevation of well 626 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Clay, sand, etc.	60	60
Saginaw Coal Series:		
Gray sandstone.	40	100
Blue shale.	20	120
Black shale.	10	130
Upper Grand Rapids:		
Blue and gray limestone.	70	200
Gray sandstone.	40	240
Lower Grand Rapids:		
Blue rock.	40	280
Shale?	20	300
Shale?	30	330
Blue rock.	60	390
Blue shale.	10	400
Hard gray rock; streaks of shale; big flow of water.	50	450
Upper Marshall or Napoleon Sandstone:		
Gray sandstone, rapid drilling.	200	650
Lower Marshall Sandstone:		
Red sandstone and blue shale (brine easily exhausted.) Blue shale with some red shale.	250	900
Coldwater Shale:		
Mostly blue shale. Some water at the top.	100	1000
Blue shale, some brine but scarce.	400	1400
Blue shale.	400	1800
Berea Shale:		
Black shale, some water.	50	1850

CHAPTER X.

NORTHERN PENINSULA.

THE PALAEOZOIC AREA.

That part of the Upper Peninsula west of a line drawn from Marquette to Menominee is mainly underlain by pre-Cambrian rocks. Palaeozoic rocks from the Cambrian up to and including the Silurian occupy all of the area to the east of this line.

The Niagara limestone extends in an accurate belt along the western shore of Lake Michigan through Green Bay peninsula and along the northern shores of Lakes Michigan and Huron from Garden Peninsula to Drummond Island and into Cockburn and Manitoulin Islands, Ontario. The St. Ignace Peninsula, however, is composed of Monroe beds.

The Niagara in the Upper Peninsula is a massive limestone and dolomite formation with an average thickness of about 600 feet. The prevailing dip is lakeward from 40 to 60 feet per mile and this gives rise to low rocky shores with few deep harbors. Toward the interior the rock surface rises to considerable heights and the outer margin of the formation is marked by a prominent line of landward facing bluffs 100 to 200 feet high. The elevation of the interior and the lakeward dip of the rocks give rise to general artesian conditions along the lake shore. As a consequence much drilling for water has been done at several points but as water from limestones is nearly always very hard, some relatively deep drillings have been made in search of softer waters. These drillings, together with observations afforded by extensive outcrops, indicate that the Niagara contains very little bituminous matter and that in the Upper Peninsula it gives little promise of yielding oil and gas.

The Clinton, Rochester and Medina are doubtfully recognized in outcrops or in borings and can not be distinguished from each other. The Lorraine and the Utica are well represented and are easily recognized in drill holes. These shaly formations, being very soft, occur in a belt of depressions on the north side of the Niagara escarpment and outcrop in but few places. The Utica shale is exposed in the beds of streams on the east side of Whitefish river.

The Trenton limestone forms the western shore of Green Bay and

Little Bay de Noc, turns eastward in Delta county, describing an arc through the Northern Peninsula, and crosses St. Mary's river at St. Joseph Island into Ontario. Nowhere in the Northern Peninsula is the Trenton very deep, yet it offers certain oil and gas possibilities, for, aside from its bituminous and petroliferous character, it has a suitable cap rock, being overlain in most of the Peninsula by the impervious shales of the Utica and Lorraine.

The Trenton outcrops over a very large area and in general is under a very thin cover of drift in the vicinity of Rapid and Whitefish rivers. Wherever exposed, it shows signs of the former presence of oil and gas. The rock is bituminous and petroliferous and very frequently the cracks and fissures are found to contain dried oil residue or asphaltum "gum."

Comparatively little exploration has been done in the Upper Peninsula except for water. Thus far wells have been sunk at Marinette (Wisconsin), Menominee, Rapid River, Escanaba, Gladstone and Flat Rock, near Stonington, at Pickford, Neebish Island, and St. Ignace.

THE WISCONSIN SECTION.

Milwaukee. In order to show the relation of the eastern Wisconsin rocks to the Michigan Basin, the following log of the Lake Park well is given below. Comparing it with the western Michigan borings, it is to be observed that the formations in eastern Wisconsin are merely the western edges of the lower formations of the Michigan Basin. The dip from Milwaukee across Lake Michigan to Muskegon is rather flat, being only about 20 feet per mile. Farther north in the Northern Peninsula the dip toward the center of the Basin becomes much greater ranging from 40 to 60 feet, or even more per mile.

LAKE PARK WELL, MILWAUKEE.

	Thick- ness, feet.	Depth, feet.
Hamilton (Traverse) Group:		
Soapstone.....	80	80
Cement rock.....	12	92
Soapstone.....	30	122
Dundee absent:		
Waterlime? Brown limestone.....	30	152
Niagara limestone.....	320	470
Cincinnati shale (Medina to Utica).....	180	650
Galena and Trenton limestone.....	300?	950?
St. Peters sandstone at.....		958
Potsdam sandstone.....		?

Marinette. A number of wells were sunk in Marinette by the Hon. Isaac Stephenson, A. C. Merriman, and the city at the waterworks.

The record of Mr. Stephenson's well is incomplete, but the well apparently penetrated limestone and dolomite and a little light reddish sandstone, and a thin stratum of shale in the first 200 feet. A flow of water was struck in a crevice in the Calciferos (or the St. Peters) at 405 feet. At 410 feet, there was a large crevice, the tools dropping four feet and breaking the cable. The flow of water from this crevice was stronger and rose 21 feet above the surface. Below this point there was no increase in the amount of water though the well penetrated mainly lime rock until "granite" was struck at 716 feet. The granite, according to Lane, is probably a cherty or jaspilitic arkose quartzite which was struck in a later well drilled at the waterworks.¹

At Oakwood, three miles south of the city, it was claimed that a well reached a depth of 999 feet, but the samples at 860 (white sand) and at 920 feet do not resemble the Huronian rocks which should be struck at those depths. From a comparison with the records of other wells in the vicinity there seems to have been a mistake of 100 feet in the record.

A well two miles south of the Stephenson well was drilled in 1902-3 for oil and gas to the depth of 850 feet. This well may have reached the pre-Cambrian as red "sand," similar to Huronian well samples from other wells, was struck at the bottom.

The first deep well drilled at the city water works was not completed as the tools were lost in the hole and could not be recovered. Another hole was drilled about 8 feet away and this struck the first hole at about 860 feet. Artesian water, struck above 860 feet in the second well, flowed out of the first after the intersection of the two. The tools were deflected on the old ones in the bottom of the first well and the hole was drilled to the depth of 978 feet, penetrating over 180 feet of Huronian rocks. The well yielded a little oil along with the water, but the oil probably came from the vugs or cavities in the limestone and not from the pre-Cambrian rocks as supposed by some. In the Rapid River well, Delta county, oil occurred in limestone in this way and at the same horizon.

¹Ann. Rept. for 1903, p. 123.

MARINETTE WATER WORKS WELL NO. 1.

Loc.: Waterworks, Marinette, Wis.

	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Red sand and gravel	70	70
?	15	85
Galena limestone:		
Round chipped limestone (or to 196 ft.)	59	144
Trenton limestone:		
Blue shales (Galena?)	52	196
Chipping limestone coarse	44	240
Chipping limestone	10	250
"Slate" light blue and white	70	320
(Base of Trenton uncertain, St. Peters sandstone absent?)		
Lower Magnesian (Calciferous) limestone:		
Chipping limestone, coarse	130	450
Coarse chipping limestone light colored and dolomitic	100	550
Potsdam group?:		
White sandstone, very white, mealy-looking	10	560
White and greenish, calcareous sandstone	110	670
White sand	15	685
Rounded white sand	27	712
Huronian? (Potsdam wholly or in part?):		
"Granite" (broken and lost)	4	716
Dark red quartzite	?	716 +

MARINETTE WATER WORKS WELL NO. 2.

	Thick- ness, feet.	Depth, feet.
Surface sand and gravel	69	69
Galena dolomite	121	190
Trenton dolomites, brown and blue shaly (at 260 to 275 sandy)	135	325
St. Peters sandstone	75	400
Calciferous (Lower Magnesian)	180	580
Potsdam	215	795
Pre-Cambrian:		
Cherty or jaspilitic arkose quartzite	183	978

MENOMINEE COUNTY.

Menominee. Several deep wells have been sunk in Menominee just across the river from Marinette. The records of all of the wells are incomplete and are of little value. A well drilled in 1895-6 at the residence of the Hon. S. M. Stephenson is reported to be 500 to 1000 feet deep. The water has a head of 15 feet and it is said to come mainly from sandstone, perhaps the Potsdam. A well on Mr. Stephenson's farm which, like the one at his residence, begins in the Trenton and perhaps reaches the pre-Cambrian. The water is hard, therefore it probably comes from limestone.

DELTA COUNTY.

Escanaba. In Delta county, there are several wells from 600 to nearly 1000 feet in depth. In 1890 the Escanaba Brewing Company drilled a well for soft water 730 feet in depth at Escanaba, but only a meager record was obtainable. The record below is given from memory by Nick Welch:

ESCANABA BREWING COMPANY WELL.

	Feet.
Surface.....	39
Limestone.....	150-200
Sandstone.....	300-400
Struck "Iron" at.....	730
Water very red.	

The Escanaba Manufacturing Company made a drilling to a depth of 972 feet for water, but no record was kept. The Richter Brewing Company also drilled a well 810 feet and the record furnished by the brewmaster, Mr. Richter, is one from memory:

RICHTER BREWING COMPANY WELL.

	Feet.
Sand.....	50
Hard clay.....	9
? ((probably limestone mainly).....	300
Sandstone.....	410
"Granite" at.....	810

Stonington. A. Wagner drilled two holes on his farm, three or four miles northeast of Stonington and, according to reports, the first was for coal and the second, a diamond drilling for iron. Mr. J. Wagner, present owner of the farm, furnished Mr. L. P. Barrett of the Survey with a record given from memory. A core was preserved but Mr. Barrett was not permitted to see this.

A. WAGNER WELL.

Loc.: Delta county, S. W. $\frac{1}{4}$ of N. W. $\frac{1}{4}$ of sec. 8, T. 39 N., R. 21 W. Drilled for coal. Formerly A. Wagner farm; present owner Jno. Wagner.

Elevation over 650 ft. A. T.	Thickness, feet.	Depth, feet.
Pleistocene:		
Gravel and clay	9	9
Lorraine (Hudson River):		
Blue shale	45	54
Fossiliferous shale	13	57
Brown shale	28	95
Blue shale	20	115
Brown shale	8	123
Gray shale	70	193
Light gray shale	8	201
Utica:		
Bituminous shale	50	251
Trenton limestone:		
Galena:		
Limestone	83	334
Fossiliferous limestone	55	389
White limestone	8	397
"Upper blue" of Wisconsin, Trenton?		
Dark limestone	9	406
"Upper buff?"		
Quartzite (geods?)	6	412
Limestone	44	456
Quartz (geods?)	1	457
Limestone	24	481
"Lower blue."		
Blue shale	4	485
Black limestone	14	499
Limestone	19	518
Blue shale	4	522
"Lower buff."		
Sandstone, soapstone and limestone (perhaps in part St. Peters)	38	560
St. Peters:		
Red clay shale (weathered surface of Lower Magnesian?)	1	561
Sandy shale	1	562
Calcliferous:		
Limestone, soapstone and sandstone	66	628
Crystalline limestone	12	640
Depth of hole		640

A. WAGNER HOLE NO. 2.

Loc.: S. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$, sec. 8, T. 39 N., R. 21 W. Formerly A. Wagner farm; present owner, Jno. Wagner. Three or four miles northeast of Stonington. Drillers, Gunter of Escanaba and Chris. Skaug of Stonington. Drilled about 1910.

Elevation over 650 feet.	Thickness, feet.	Depth, feet.
Surface:		
Sand and gravel	8	8
Clinton, Medina, Lorraine and Utica:		
Fossiliferous limestone	32	40
Alternate shale and limestone	200	240
Bituminous shale (Utica in lower part)	250	490
Trenton, Calcliferous, St. Peters, Potsdam:		
Limestone, sandstone and blue shale	490	750
Hematite. Two veins two and seven inches thick, interbedded in sandstone (Huronian?)	1	751
Sandstone	29	780
Huronian:		
Hard white quartzite with pebbles in it	68	848

Gladstone. The St. Paul and Ste. Marie railroad drilled a well for water at Gladstone, but the precise location is not given.

ST. PAUL AND STE. MARIE RAILWAY WELL.

Loc.: Gladstone.

Elevation 605 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene or surface:		
Sand (old dug well).....	13	13
Quicksand.....	38	51
Till (clay and hardpan).....	10½	61½
Sand and gravel.....	15	76½
Clay and limestone.....	10½	87
Boulders.....	4	91
Trenton:		
Limestone.....	234	325
St. Peters:		
Lime and sandstone in mixed layers. Some water at 400 feet.....	89	404
Calcliferous (Lower Magnesian):		
Limestone (crystalline dolomite at 632 feet).....	228	642
Potsdam:		
Shell sandstone (white round sand at 742 ft.).....	101	743
Main water flow; 150 gallons per minute. Soft water.		

Rapid River. In the central part of Delta county, there are a number of water wells, mainly artesian, said to be from 250 to 900 feet in depth, as at Flat Rock, Lathrop, Maple Ridge, Parkins, Gladstone, and Rapid River. In some of the more northerly wells, it is only from 80 to 150 feet to the water bearing sandstones. At Rapid River, a dozen or more wells are supposed to be deep enough to go through the Trenton, which yields strong flows of water.

Seven miles north and two miles east of Rapid River, a well was drilled for oil. The set of samples taken for the Survey was stolen so that a very incomplete and perhaps inaccurate record can be given. The surface rock is the Trenton which apparently consists of about 300 feet of more or less oily and bituminous limestone. The rest of the well is largely in white sandstone, except at the bottom where decomposed schist of Huronian or Archean age was struck. There were strong flows of water, probably from the same horizons as in the Rapid River wells. A small quantity of oil was obtained in the Trenton. According to newspaper reports at the time, the flow, greatly exaggerated, was given as 400 barrels per day. The oil probably came from the vugs or cavities in the Trenton limestone rather than from the Archean rocks as was claimed at first.

The following record was made from scattered samples.

RAPID RIVER WELL.

Loc.: Two hundred paces W., 505 S. of N. E. Cor. of sec. 34, T. 42 N., R. 21 W.; 7 mi. N. and 2 mi. E. of Rapid River.

	Thick- ness, feet.	Depth, feet.
Surface:		
Swamp peat and muck.	3-6	6
Marl.	10	16
Fifteen ft. 10 in. casing.		
Trenton limestone:		
Dolomite with geods lined with fine dog-tooth spar calcite and filled with oil "gum".	264	280?
St. Peters horizon:?		
Signs of oil. Strong flow of water, over 1 quart a second. Temperature 47° 3 F.		
An old well 300 ft. west was 202 ft. deep.	350	630
Calcareous?		
S. at 620 box 380, a dolomite.		
Potsdam sandstone:		
"White sandstone comes in 600-700 ft. down," Clear white glass sand (Upper Potsdam of Rominger).		
Samples, boxes 300 to 370.	80	710
Reddish sandstone coarse:		
Sample, box 290.	10	720
Coarse red sandstone.		
Sample, boxes 250 to 280.	40	760
Feldspathic sandstone.		
Box 290.	10	770
Coarse mixed very micaceous red sandstone.		
Box 210-230.	30	800
Last samples, large fragments of decomposed chloritic schist, like Archaean rocks.		

Another well 1000 feet in depth was drilled a year or two later 7 miles northeast of Rapid River on the property of A. E. Neff. This record is more satisfactory than the foregoing one and shows that the pre-Cambrian is at comparatively shallow depths in the vicinity of Rapid River. The following record was compiled from samples.

A. E. NEFF WELL.

Loc.: Seven miles N. E. of Rapid River, Mich. Owner, A. E. Neff. Driller, Cisco.
Drilled in 1904.

	Thick- ness, feet.	Depth feet.
Surface materials.....	12	12
Trenton limestone:		
Top limestone—dark, mixed, some sand.....	218	230
Limestone—mixed brown and blue.....	60	290
No record 290-302.....	12	302
St. Peters:		
Sand—round quartz sand, white.....	18	320
Calcareous:		
Limestone—fine grained, white, massive.....	35	355
Sand—clean, white, quartz sand.....	20	420
Sandy lime—white powder.....	10	430
Sand—clean white quartz sand.....	20	450
Sand—white dolomitic powder.....	25	475
Sand—quartz and white dolomite mixed.....	25	500
Sand—cemented by dolomite.....	30	530
Cased 9 5-8 in. pipe.		
Slate—dull bluish.....	25	555
No record 565-630.....	75	630
Lake Superior or Munising Sandstone:		
Gray, sandy round quartz and rarely other grains.....	45	675
Red sandstone—light pinkish quartz grains.....	35	710
White sand—white quartz grains.....	15	725
Red sand—pinkish quartz grains "725 grit." Water flow.....	25	750
Sand—mica, quartz, feldspar, etc., mixed.....	30	780
Sand—mica, quartz, feldspar, chlorite. Arkose? but not rounded. "780 red granite".....	50	830
No record 830-875 +.		
Pre-Cambrian:		
Rusty, much mica. "Wedged in bottom from description in gabbro".....	125	875 +
Quartz and feldspar? a pounded aplite?.....		890 +
Feldspar, chlorite, mica hornblende.....		900 +
Fine grained dark feldspar, chlorite, etc.....		1000 +
Bottom.....		

Oil and Asphalt. In many places there is an asphaltic oil in the cavities of the Trenton limestone. The oil is a more or less semi-fluid, dark brown to almost black oil residuum or asphaltic "gum." The "gum," according to Fr. Ruschaupt of Milwaukee, who made some analyses and tests, is odorless until heated and then gives an asphalt smell, foams at 185° F., fully liquid at 200°, foams from 300° to 350°, slightly decomposes at 430° with an evolution of a small amount of empyreumatic matter and boils at 556°. After about one and a half hour's boiling the asphaltic gum thickens and the boiling point rises. Boiling the residue at 600° F. for three-quarters of an hour and then cooling to 70°, gave a hard tenaceous asphalt. There is no

paraffin or petroleum in the distillate, gum asphalt being the only base. The results of two tests by Fr. Ruschaupt are given below:

ANALYSES.

	No. 1. Percent.	No. 2. Percent.
Distilled at 212° to 347° (mainly water).....	25	2.21
Distilled at 570° to 600° (mainly oil).....	45.36	46.55
Asphalt.....	24.56	46.73
Balance ash or decomposition products.....	5.08	4.51
Total.....	100.00	.....

Upon the supposition that a great pool of asphalt exists in a "synclorium" in northern Michigan, a company was formed in Milwaukee to prospect for commercially important quantities but nothing came of the project. Oil might be found in quantity in the Trenton, especially in those regions where the formation is overlain by the Utica and Lorraine shales.

The wells of reliable record are so scattered in Delta county that there are no indications of favorable structures such as anticlines or benches. The general dip is southeasterly at from 40 to 50 feet per mile, but since no wells of accurate record on the opposite side of Lake Michigan reach any of the horizons represented in the region under discussion, no exact calculations can be made.

SCHOOLCRAFT COUNTY.

Manistique. At Manistique, the flowing wells are from 200 to 800 feet in depth. At 800 feet in the Hiawatha House well, a flow was struck which lifted the drill. The head was 30 to 40 feet and the water bearing stratum is in a "not hard, shell rock," probably the Trenton. The wells furnishing the municipal supply obtain their water from depths between 250 and 500 feet. The deepest well was drilled for salt but the tools were lost in the hole. The water is hard as it is from limestone. Possibly soft water could be obtained from the Potsdam, but the depth probably would be at least 1400 feet or much greater than at Escanaba.

In 1903 a number of new city wells were put down. Mr. Coleman, the driller, gave the following record:

MANISTIQUE MUNICIPAL WELL.

Loc.: Cor. of Garden Ave. and Potter St. Finished August, 1903.

Elevation 595 ft. A. T.	Thick- ness, feet.	Depth, feet.
Sand.....	2	2
Dolomite, light buff, massive.....	2	4
Light dolomitic limestone.....	9	13
Bluish white dolomite (harsh feel).....	11	24
Brownish crystalline dolomitic limestone.....	16	40
Light bluish dolomitic limestone.....	12	52
Buff crystalline cherty limestone.....	13	63
White limestone.....	7	70
Buff, crystalline dolomitic limestone.....	10	80
Hard drilling from 0 to 80 ft.		
White limestone (Blaney—Fiborn bed?).....	27	107
Mottled gray dolomite.....	18	125
Buff dolomite.....	11	136
Soft drilling from 80 to 140 feet.		
Yellow dolomite.....	22	158
Gets harder; very little water at 140 feet but no flow.		
Yellowish limestone.....	30	188
Yellowish dolomite.....	12	215
This may be base of coralline, top of Byron beds of Wisconsin, Rominger's lower division.		
White thin banded lithographic dolomite.....	10	225
At bottom white limestone.....	15	240

All of the above wells are artesian and the flows are from the Niagara, with the exception of the Hiawatha House well, which probably obtains its flow from the Trenton. Usually, abundant water is found in the Niagara from 60 to 70 feet below the top as shown by other wells which penetrate this formation in Michigan and Ontario.

In the Manistique region, the Trenton, which is locally very porous, is overlain by the Utica, the Lorraine, and the Niagara, and, should favorable structures exist, oil and gas may occur in commercial quantities. The shallowness of most of the wells and the incomplete records of the deeper ones do not permit a close approximation of either the general or the local dip, and much less, a determination of the presence of local structures. From surface observations, however, the dip appears to be fully 40 feet per mile to the southeast.

MACKINAC COUNTY.

St. Ignace. In 1887, the Mackinac Lumber Co. drilled a well at St. Ignace to the depth of 919 feet. As the rocks on the St. Ignace peninsula are practically all of Monroe age, good water supplies are hard to obtain, the surface waters and those from bed rock being strong in sulphates. Plenty of good water, though hard, may be found in the Niagara. A cherty layer at the bottom of the well yielded some gas.

ST. IGNACE WELL NO. 1.

Mackinac Lumber Co. O. W. Johnson, Racine, Wis. W. A. Burt. Drilled in 1887 by Henry Errata.

Elevation about 600 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Sawdust and clay.....	15	15
Monroe Formation:		
Red and blue slates, principally red. Strongly impregnated. Salt water with a bitter taste.....	385	400
Red marl and a vein of salt.....	4	404
Blue slate.....	100	504
Niagara (Guelph and Lockport):		
Limestone (contains a little dolomite and gypsum.) Very light buff. Dolomite with slow eff. Upper strata are probably Monroe; see well No. 2.....	300	804
Driller's name, sandstone; with a strong smell, oily. S. white limestone; contains a little gypsum, 2 per cent.....	95	899
S. Calcareous sandstone (gray); 90 per cent chert, etc.; rusty. Some gas	20	919

St. Ignace Well No. 2. Well No. 2 at St. Ignace is about two miles north of the old well, 300 feet from Lake Huron, and only about 10 feet above lake level. A comparison of the two wells show that the beds dip rather steeply, the dip being over 40 feet per mile. Neither of these wells show the Medina, Lorraine, or Utica. The Lorraine and Utica are known to exist in the Upper Peninsula and from the Neebish well the total drop of the formations must be over 1200 feet in 30 miles, or over 40 feet per mile. If 500 feet is allowed for the thickness of the shaly beds, above the Trenton, the total drop would be over 1700 feet, which would be equal to a dip of about 55 feet per mile from Neebish southwest to St. Ignace. As the general dip is nearly south and not southwest, the maximum dip is probably 60 to 65 feet to the mile.

ST. IGNACE WELL NO. 2.

Loc.: Two mi. north of No. 1 on sec. 31, T. 41 N., R. 3 W.; 600 ft. N. of town line and 300 ft. from Lake Huron.

Elevation 590 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Surface.....	34	34
Gravel with gypsum.....	9	45
Monroe Formation:		
Dolomite.....	63	to 89
Dark dolomite.....	100	to 104
Gypsum.....	174	to 187
Red shale.....		
Blue shale.....		
Gypsum.....	255	to 260
Red shale.....		
Blue shale.....		
Gypsum, about.....		300
Blue shale with gypsum at 329 and 364 to 400 ft. and other spots to 426 feet.....	126	426
Gypsiferous dolomite.....	18	444
Light dolomite.....	19	463
Dark brown dolomite.....	47	510
Niagara (Guelph):		
Light dolomite.....	60	570
White sandy dolomite.....	15	585
Good water at 575 ft. 589 ft., January 29.		
Hard mixed cherty dolomite.....	7	592
White sandy dolomite.....	196	788
581 ft. Feb. 10; H ₂ S water for over 100 ft.; 870, March 23.		
Brown and mixed dolomite.....	232	1020
Lockport (?):		
Limestone.....	90	1110
Rochester (?):		
Blue shaly dolomite.....	35	1145
Brown cherty dolomite.....	5	1150
Light dolomite.....	16	1166

CHIPPEWA COUNTY.

Neebish A well was drilled on St. Joseph's Island to the depth of 200 feet and, according to reports, it penetrated the Huronian without striking oil. No further details are known. On Neebish Island, near Sailor's Encampment and close to the water, a well over 527 feet in depth (563 feet according to the Michigan Miner), was drilled by A. W. Palmer for the American Alkali Company. It appears that the drilling began in the top of the Trenton, but if this is true the Trenton must be very thin.

Dr. Lane considers that the bottom of the well is in conglomeratic Potsdam and that the limestone is in part Trenton. The white sugary sandstone appears to be Calciferous, and, in that case, the St. Peter is absent as at Pickford. The top of the Potsdam is locally very similar to the St. Peters, and if the Calciferous is absent the two may be easily confused.

The record given below is chiefly that of the driller. Notes on the samples and the record are given in brackets. The correlations are by W. Alden of the U. S. Geological Survey.

NEEBISH WELL.

Loc.: Near Sailor's Encampment, Neebish Island, or across the west channel on the mainland opposite Trombleys and about 1000 ft. south of north line of Trombleys; about 100 ft. from river, 6 or 7 ft. above water, and about 1½ miles below the rapids in the river. Reported by A. W. Palmer, Jan. 15, 1900.

Elevation about 587 ft. A. T.	Thick- ness, feet.	Depth, feet.
Surface:		
Clay, boulders and sand.....	33	33
Trenton limestone:		
Limestone, hard.....	1	34
Limestone, vein water, soft.....	1	35
Limestone, hard.....	14	49
Limestone, gritty, softer.....	40	89
Limestone, darker in color, not so gritty but harder (111-138 light colored).....	17	106
Limestone, softer.....	13	119
Limestone, shale.....	2	121
Limestone, hard.....	3	124
Limestone, softer.....	3	127
Limestone, hard.....	7	134
Limestone, softer.....	6	140
Limestone, shale.....	2	142
Limestone.....	7	149
Limestone, hard (148-158 light colored).....	4	153
Limestone, softer.....	5	158
Limestone, shale (bluish, thin chips).....	5	163
Limestone, brittle (bluish, chipping, 163-200).....	22	185
Clay.....	1	186
Limestone, brittle.....	4	190
Shale; cased here for first time.....	8	198
Limestone.....	2	200
Shale (large chips, thin bedded).....	5	205
Limestone, darker in color (sandy dolomite).....	9	214
Limestone, shelly, full of little seams.....	9	223
St. Peters (Calcliferous?):		
White sand rock.....	10	233
Shale.....	2	235
White sand (glass sand) rock, got first flow water at 250 ft., and more in several places in going through the sand.....	149	384
Potsdam:		
Light red sand.....	27	411
Sand; harder, looks like granite boulders pounded up.....	6	417
Pre-Cambrian:		
Sandy shale; sand pumpings look red but when washed out are black. (Coarse red conglomerate; grows coarser).....	89	506
Sand rock.....	21	527
(At 430 ft. red pebbles of Huronian quartzite; 506-510 ft. and 510-527 ft. material mainly Huronian.)		

Pickford. In 1906-1907, a deep well was drilled for oil at Pickford, Chippewa county. A heavy flow of water with a 25 foot head was struck somewhere below 1000 feet, probably about 1400 feet. There was some water between 500 and 800 feet, but it would rise to the top of the casing only on standing over night. Very little signs of oil and gas were struck anywhere, though an oily sandstone was encountered toward the bottom of the well. The record, compiled by Dr. Lane from a partial set of samples down to 1000 feet, is as follows:

PICKFORD WELL.

Loc.: Sec. 6, T. 43, N., R. 1 E. F. G. Holden, H. D. Van Campen, Sault Ste. Marie; Mr. Taylor, Pickford.

Elevation about 670 ft. A. T.	Thick- ness, feet.	Depth, feet.
Pleistocene:		
Lake Superior red clays.....	119	119
Sand, source of local flows of water.....	13	132
Described by Leverett. Head 6 to 7 ft., light flow.		
Niagara (Lockport):		
Hard dolomite; slow eff., a few loose shaly layers at top; then very hard.	128	260
About 3 miles S. of town the land rises to the Niagara escarpment.		
Lorraine:		
Blue shale.....	215	475
Utica:		
Black shale, "slate".....	50	525
Trenton limestone:		
White limestone; ready eff.; residue of pyrite cubes and chert.....	275	800
St. Peters:		
Thickness unknown.....		600
Water at 600-700 ft. said to be in white sandstone but it is doubtful; no samples.		
Samples of water 575 to 650 ft. show 70-79 per million Cl and are hard and have SO ₄ .		
Calciferous?		
At 800 ft. 10-24-06 Iron Mtn. Tribune-Gazette.		
Potsdam or Lake Superior sandstone.....	700	1500
Red rock at 800-900. (Holden.)		
J. L. Ward also thought they passed Trenton at 900 ft.		
Said to be muddy. (VanCampen.)		
At 1360' red as blood. (J. L. Ward.)		
Flow of water March 22, '07 "warm."		
Into an oily sandstone—Detroit Times.		
VanCampen thought the casing was crushed at 1200-1300 ft. Water flowed with over 25 ft. head.		
Depth—Marquette Mining Journal, 3-23-07, 1500; 6-7-07, 1425.		

Concerning the interpretation and the correlations, Dr. Lane makes the following statements:

"Down to the top of the Trenton, the record is verified by samples and agrees perfectly with other holes; below that, it must be made out by statements from memory, and the only thing of which one can be reasonably sure is that it struck the red Potsdam above 1360 feet and probably at 800-900 feet and did not penetrate the Huronian. The most that can be said of the correlation above is that there is nothing known to make it impossible. The Neebish Island well shows that there is about 400 feet or more between the Utica and the red sandstones there; at Wagner's well (near Stonington) there was 310 feet. And here, there is (525 to 800 or 900 ft.) 373 feet or less. This must then include the Trenton, St. Peters, Calciferous, and perhaps the upper white part of the Lake Superior sandstone, affiliated with the Calciferous.

The water at 600 feet is hard, a regular limestone water and does not suggest the St. Peters. There will hardly be less limestone than in the Neebish well and along St. Mary's river and it makes a conspicuous ridge to the north. The dip seems to be about 66 feet to the mile to the south and, with any such dip, the Trenton must be 200

feet or so thick, judging from the breadth of the outcrop. Not only that, but the Neebish well shows a good thickness (Alden thinks 112+ ft.) for the Utica does not show, and the Manitoulin Island wells also show 250 feet, which is assigned to the Trenton. It seems most likely that the Calciferous has been eroded and the St. Peters and Potsdam can not be separated."

Assuming that the Niagara has its average thickness of 600 feet at Pickford, if it were not eroded, the dip of the Niagara, as calculated from its projected top toward the center of the Basin, would be only about 50 feet per mile instead of 66 feet as suggested by Dr. Lane for the lower beds. As the Lorraine thickens toward Cheboygan the dip would be greater for the Trenton. In any case, the dips of the strata in the Northern Peninsula are prevailingly greater than in the Southern.

MANITOULIN ISLAND, ONTARIO.

Gore Bay. In 1904-05, several oil wells were drilled on Manitoulin Island, and the record of one is given by M. J. L. Ward. Some oil was struck at 425 feet, about 85 feet below the top of the Trenton.

GORE BAY WELL.

	Thick- ness, feet.	Depth, feet.
Pleistocene or drift.....	1	1
Niagara:		
Limestone extra hard and gray.....	45	46
Rochester:		
Blue shale.....	89	135
Clinton? Lorraine?		
Limestone.....	1	136
Shale.....	29	165
Limestone.....	1	166
Lorraine:		
Blue shale.....	90	256
Utica shale:		
Brown shale.....	60	316
Black shale.....	15	331
Trenton limestone:		
Limestone.....	250	581
Oil at 425 ft.		

APPENDIX A.

THE REGULATION OF DRILLINGS AND CARE OF DEEP BORINGS.

In all oil and gas fields a larger or smaller percent of the wells drilled are dry holes or holes with a yield which is too small for profitable operation. In "spotted" fields, such as in Randolph county, Indiana, 40 per cent of the wells may be dry. In many fields, such wells are abandoned without plugging with the result that water, which is generally encountered at one or more horizons, makes its way into the oil and gas sands with disastrous consequences. Sometimes the casings are left in the wells but this is only a temporary protection as the corrosive action of the brines or mineral waters generally will destroy ordinary casings in two to five years.

Most oil and gas bodies are surrounded by salt water but this water, known as "edge water" invades the reservoirs only as the oil and gas are withdrawn (providing these products are not withdrawn at too rapid a rate), so that a maximum recovery is possible. When water is introduced directly into the productive portion of a field through an uncased, or improperly cased well, the oil is forced back into the sand, so that pumping may produce nothing but water. As the sheet of advancing water reaches other wells, their production becomes partly, or entirely water, and the final result will be the ruin of the entire field.

In the older oil and gas fields of the country, little or no attention was given to abandoned and unplugged wells and the life of many pools has been greatly shortened or abruptly terminated by the flooding of the sands by water. In California¹, investigations by the State Mining Bureau has disclosed the fact that the productivity and life of many of the oil fields of that state are menaced by water from improperly cased and unplugged wells. Reports obtained from 41 per cent of all the wells in operation show that 25 per cent of these wells produce from 10 to 50 percent or over of water. Similar menacing conditions exist in most of the fields of the country, and had proper means and methods been used in the drilling and care of wells, these conditions could have been largely avoided.

Abandoned or improperly cased wells are not only a menace to pro-

¹R. P. McLaughlin, Preliminary Reports on Petroleum, Nos. 1 and 2, Cal. State Mng. Bur., 1914.

ductive wells in an oil and gas field, but they are a source of pollution to potable waters or valuable brines and mineral waters. Brines or mineralized waters from one horizon may invade another containing fresh water, or, vice versa, fresh water may find ingress to brine bearing or mineral water strata. In the first case, supplies of potable water, the most valuable of the natural resources, are destroyed and, in the second, the quality of the brines or mineral waters is injured or ruined.

Along Saginaw river, most of the former supplies of fresh water in the surface deposits have been ruined through leakage from the abandoned salt wells unplugged or improperly plugged. In the vicinity of Grand Rapids, drillings for salt and gypsum have permitted the sulphate brines of the Michigan Series to percolate down into the underlying Marshall, and, locally, the former supplies of fresh water in this formation have been destroyed. As these old test holes and many others scattered over the State are still unplugged, the injury to valuable supplies of brine and fresh water grows greater from year to year. The above cases are not exceptional but are rather typical of conditions obtaining in many portions of the country.

Many oil and gas fields are located in coal fields, particularly is this the case in Pennsylvania, West Virginia, Ohio, Indiana, Illinois, Kansas and Oklahoma. Oil and gas wells penetrating workable coal seams or active mines add greatly to the hazards of mining on account of the danger of the escape of gas or oil into the mines with the consequent danger of explosion. The casings may be improperly placed, breached by the corrosive action of brine or mineral water, broken by the caving or subsidence of the overlying strata subsequent to the mining of the coal, or removed upon abandonment of the wells. In several instances, severe explosions of natural gas from this source have occurred in coal mines, and many others have been narrowly averted.

In Pennsylvania, there are over 50,000 oil and gas wells in coal territory, and it is estimated that 3000 new wells are drilled each year, 2000 of which are abandoned. Most of the latter are abandoned without being properly plugged or charted. Many of these though not producing commercial quantities of gas, yield enough to cause explosions and fires, if it were to leak into a mine. In some localities, the oil and gas wells are so numerous and close together that they not only seriously interfere with mining operations but cause much loss of coal through the large pillars which must be left to protect the wells. Owing to the close drilling and the number of unplugged and uncharted wells, the leases on certain coal properties in Pennsylvania have been surrendered on the ground that the estimated recovery of

coal is too small and the hazards too great to pay for mining. In addition to the danger from gas and the loss of coal noted above, water from unplugged and uncharted wells may flood the mine workings. This has happened in a number of cases. Water, under a head of 400 feet, broke into two mines in Illinois in 1912 and caused much trouble and expense before it was controlled.

Since many of the older oil and gas fields have been redrilled from one to three times and tens of thousands of holes are being drilled in coal territory, hitherto unprospected for oil and gas, the situation between the coal and the oil operators has become acute. A number of states have passed laws with the aim of protecting and conserving the oil and gas resources, but only in Ohio, Indiana, and Illinois have measures been enacted to protect the coal mines and coal reserves from the dangers of the promiscuous drilling of oil and gas wells. The laws, however, in all of these states are inadequate.

On the other hand, mining operations are a menace to the oil and gas wells. As noted previously, the slumping of the strata after the removal of the coal or other minerals may bend or break the casings and ruin some of the wells. The broken casings in the case of abandoned mines also permit the entrance of water to the sands with consequent injury to the field.

As a result of these conflicting interests, a bitter antagonism has grown up between the coal and the oil and gas operators. Manufacturing concerns utilizing brines and mineral waters also look with disfavor upon drillings which endanger the purity and strength of their supply of these substances.

It is most regrettable, that in the past the public at large has displayed only an apathetic interest in the conservation of the potable water supplies. Owing to the wave of agitation for the conservation of the natural resources, which has swept over the country during the past few years, strong efforts have been made in many states to secure adequate laws regulating the drilling and care of deep borings, more particularly those for oil and gas. In certain states, opposition on the part of the oil and gas interests has been successful in defeating every attempt at securing much needed legislation on this subject. Oklahoma, California, Wyoming, Illinois, and a number of other states, however, have passed remedial and protective measures. Unfortunately, in some states, the measures are rendered almost nugatory through failure to provide for proper administrative machinery, sufficient funds, or adequate penalties for violations of the law.

In Pennsylvania and West Virginia, the law requires that abandoned wells must be plugged, but there is no competent executive officer to see that the requirements of the law are properly complied with. In

Ohio, owners of wells must notify the Salt Mine Inspector ten days prior to the contemplated abandonment of a well so that, at his discretion, he may notify a district mine inspector to be present when the well is plugged. A man may be an efficient mine inspector but incompetent to supervise the plugging of an oil or gas well. Moreover, mine inspectors, beyond the protection of the coal mines have little interest in the protection of oil and gas sands or water and brine horizons. In the California laws, there is no provision for a central executive authority. The drilling and care of wells is left to the county well commissioner, who is appointed at the request of three or more oil companies operating in the country. The Indiana laws of 1903 require owners upon the abandonment of a well to plug the same according to certain specifications and file an affidavit signed by two witnesses, describing in detail the manner in which the well was plugged. Since the law does not require that the State Natural Gas Supervisor shall be notified, this official has no means of knowing when a well is to be plugged or when the law has been violated, except through information furnished by outside parties. "Fly-by-night" operators take advantage of this, "pull" their casings, and seek more promising fields in other states without plugging their wells.

In Wyoming, the laws prohibit the waste of oil or gas from a well beyond a limit of thirty days, specify the manner in which wells shall be plugged, and provide penalties and liabilities, but there is no central authority to enforce the provisions of the law. No legal action is taken except on the formal complaint of an interested party.

The Illinois statutes provide that all fresh water, during the drilling and after the completion of a well, shall be kept cased off from the oil and gas sands, in addition to the requirement that abandoned wells shall be plugged. The law fails of its purpose as there is no provision for adequate administrative machinery. The only protective measure in Michigan is a law requiring that, in Saginaw and Bay counties alone, salt wells shall be plugged upon abandonment. In short, in none of the states do the existing laws relative to the regulation of the drilling and care of oil and gas wells secure the desired ends.

In order to fully protect the rights of all parties concerned, a law regulating the drilling and care of oil and gas wells or other deep borings must provide for, (1) a competent administrative body having adequate executive powers, sufficient funds and trained assistants to properly carry out the provisions of the law; (2) definite methods of (a) casing and protecting wells through beds of coal, clay or other mineral deposits, and through horizons bearing valuable brine and mineral or potable water and, (b) of plugging wells, (3) the collection

and filing of all information bearing on the geologic conditions, i. e., the character, thickness, and depth of the various formations, the water and the oil and gas horizons, (4) the formal and accurate (a) location and recording and (b) the formal abandonment, plugging, and inspection of wells; (5) the cooperation of all parties concerned; and (6) adequate penalties and liabilities for infractions of the law and for damages.

The chief difficulties in framing a workable and satisfactory law regulating the drilling and care of oil and gas or other deep borings arises from the (1) conflicting interests and (2) the variety of conditions which may be met. A law which will adequately protect the coal operator and minable coal beds may work undue hardship upon the oil and gas prospector. In some districts, there are several coal seams, some of which are of workable thickness under present conditions and others not. The term "workable" thickness is a relative one. Whether a coal bed is workable or not depends upon several factors besides that of mere thickness, viz., quality of coal, mining and labor conditions, nearness to markets, and competition. In Wales, veins of coal under 14 inches in thickness and in Missouri and Kansas beds 12 to 20 inches are operated at a profit, while in some coal fields no beds under four feet thick are being mined. With further exhaustion of the coal reserves, or with the development of new markets or cheaper methods of mining, some of the beds too thin to mine now may become workable.

The churn or percussion drill is generally used for oil and gas explorations, and, with this type of drill, it is very difficult to determine the exact thickness of coal beds and many drillers pass through workable beds without recognizing their presence. In Michigan, there are a dozen or more seams of coal, extremely variable in thickness and extent. Apparently only a few of the beds contain areas thick enough to be mined under present conditions, and these areas are very local. From this, it follows that there is no absolute way of distinguishing the different seams of coal, and it would be impossible in many cases to determine what seams should be protected. To require a driller to case off and protect each coal bed encountered would not only entail prohibitive expense, but it would be practically impossible in many cases on account of the size of the hole which would be required. The same may be said of the water and brine horizons, since, in some regions, there are a number of water or brine horizons, each yielding a water or brine differing in quality from any of the others.

The capping of oil and gas wells within a definite time limit to prevent waste may be very difficult or even impossible as in the case of the great oil wells in the eastern Mexico fields and the gas wells of

Texas and Louisiana. It cost \$3,000,000 to put out the fire and cap the great Dos Bocas well No. 2 near Tampico. In many instances, the plugging of a gas well too small to be operated is very difficult, especially where the rock pressure is very high, and it may cost several thousand dollars. To case off the salt water which occurs between the two productive oil sands in the Midway-Sunset field of California costs about \$10,000 additional per well, yet it must be done to protect the oil sands.

The designation of a specific method for the casing and plugging of wells is unsatisfactory as no one method is adequate to meet the different conditions which may be encountered in different parts of a state, or even in the same field. A given method may secure the desired results in one case, but may fail of its purpose in another. Two or more efficacious methods, however, may be outlined to meet the conditions more commonly occurring, but certain discretionary powers as to what coal beds and water and brine horizons shall be protected, and what method and means are to be used in a particular case should be given the administrative official or body, but arbitrary power over the casing and plugging of wells should not be placed in the hands of a single individual.

One of the greatest difficulties in intelligently applying the remedial and protective measures of a law lies in the lack of an organized body of information concerning the character, thickness and depth of the (1) formations, (2) the oil and gas horizons and, (3) coal beds or deposits of other minerals and mineral substances having present or possible future value. In some fields where the sands are little disturbed, regular in thickness and character and continuous over large areas, the problem of drilling and caring for wells is comparatively simple, but in fields where the sands are numerous, variable in character, discontinuous and much disturbed, and where there are several water bearing strata, some of which lie between the productive sands, the problem demands the fullest knowledge of the geological conditions and taxes the ingenuity of the most highly trained geologist-engineer.

The usual penalties prescribed in the laws of the several states are nominal fines from \$100.00 to \$500.00, or both fines and imprisonment. In those states where the maximum fine is but \$500.00 and the cost of repairing the casing of a well or of plugging a well is several thousand dollars the fine is ridiculously small in comparison. To obviate this difficulty some states have made the fine cumulative according to the length of time that the offender fails to comply with the requirements of the law.

For many years the drilling and care of oil and gas wells has been

the subject of much study and investigation. During the past few years the United States Bureau of Mines has made an exhaustive study of this subject with special reference to the danger to life and property from drillings for oil and gas in coal territory. In order to secure information bearing on every aspect of the subject, the Bureau of Mines has been in the practice of conferring from time to time with students of the subject and representatives of all interests concerned. The information has been collected with the view of formulating and recommending changes in the present practices in the drilling and care of wells, and also changes in the state laws which might prove effective by being "both reasonable and enforceable." As a result of these separate conferences, a general conference² was held February 7 and 8, 1913, between representatives of the coal operators, the oil and gas companies, the geological surveys of the various states, and the Bureau of Mines of the United States. At this conference, problems, arising particularly from the interrelations of oil and gas wells and coal mines, and tentative suggestions for the legal regulation of drillings in coal regions, were discussed at length. The tentative regulations were referred to a committee of twenty composed of three representatives from each of the interests: coal, natural gas, petroleum, state geologists, state mine inspectors, and the Bureau of Mines, together with the president and secretary of the conference. This committee met on March 1 and 10 and made a revision of the proposed regulations which was presented to the general conference on March 11. The proposed regulations as drafted by this conference are in the form of an outline³ of desirable legislation, to be developed in proper legal form to meet the industrial needs of each state.

The essential features prescribed in the proposed regulations are six in number, viz:

- (1) Accurate and formal location and recording of wells.
- (2) Cooperation of the several parties interested to obtain a safe location.
- (3) Designation of efficacious methods of casing and protecting wells through coal beds.
- (4) Formal abandonment of wells.
- (5) Safe methods of plugging wells.
- (6) Adequate inspection.

The proposed measure placed the administrative power in the hands of a single individual, the Chief Well Inspector of the state, and this is one of the objections strongly urged against it. According to R. P. McLaughlin of the State Mining Bureau of California, experience

²Bull. No. 65, U. S. Bureau of Mines, Oil and Gas Wells through Workable Coal Beds, 1913.

³Technical Paper No. 53, U. S. Bureau of Mines. Proposed Regulations for the Drilling of Gas and Oil Wells. O. P. Hood and G. Heggem.

has shown that the arbitrary power to order repairs or the abandonment of a well should not be wielded by a single individual. Other investigators hold that the control of drilling and plugging of wells should be in the hands of a commission composed of the State Geologist, the head of the State Mining Board or Inspector of Mines, and a third member chosen from the oil and gas operators. A second criticism refers to the framing of specific regulatory measures designed to protect coal mines and coal reserves without adequate protection of potable waters, valuable brines and mineral waters, deposits of clay, gypsum, limestone, shale, or other minerals or mineral substances. A third criticism may be made as to the lack of explicitness regarding the control of the chief oil and gas inspector over the kind of geologic records to be kept of each drilling. This is most necessary to the intelligent application of the remedial and protective provisions of the law, and the information contained in a log made by the average driller is far from reliable. The Chief Well Inspector should have power to prescribe the kind of record to be kept and to demand, as circumstances warrant, sets of samples of the well drillings and samples of the waters and brines encountered.

In 1912-13, the Saginaw Development Company drilled a number of wells for oil in close proximity to the salt wells in Saginaw and the operators of salt blocks were alarmed lest these borings should be abandoned without being properly plugged. The law requires that only those wells drilled for salt in Saginaw and Bay counties alone must be plugged, hence the Development Company was not legally bound to plug their borings upon abandonment. The company, however, of their own accord plugged all their wells which were near enough to contaminate the brines utilized by the salt blocks along Saginaw river.

In order to protect the fresh and mineral water, brine, coal and other resources of Michigan from the danger of promiscuous drilling and of improperly cased and unplugged wells, an attempt was made during the session of the legislature of 1913 to pass a general law covering the subject of drilling and care of wells, but the bill was permitted to languish in committee. Later, the members from the Saginaw Valley districts introduced a bill to protect the salt industry of the State but this also failed of passage. Michigan has no law governing the drilling and care of deep borings, other than the salt wells in Saginaw and Bay counties.

APPENDIX B.

BITUMINOUS OR OIL SHALES.

Before the great oil fields of the United States and Canada were discovered, the extraction of oil from bituminous or oil shales was an industry of considerable importance in the United States. Prior to the Civil War, there were 50 or 60 plants¹ in the United States distilling oil from shales and coals, high in volatile and liquid hydrocarbons. Some of the companies imported special kinds of coal but most of them used shale and coal from Pennsylvania, Ohio, Virginia, Kentucky, and Missouri. Twenty-five oil-shale plants were in Ohio and ten in western Pennsylvania, but most of the plants in the country were of small capacity and the greater number were hardly in operation before the discovery of the great oil fields of Pennsylvania and other states forced them out of business. The oil-shale industry was practically destroyed by 1865, but the operating companies in many cases saved themselves from ruin "by converting their oil factories into refineries, which was done with very little trouble."

In Scotland², unsuccessful attempts to extract oil from coal and shale began more than a century ago, and in France the distillation of shale began even earlier. James Young discovered a process of distilling oil from bituminous and petroliferous substances and began the distilling or refining of petroleum found in a coal pit. Later he experimented with various coals and, finding Boghead coal or Torbanehill mineral suitable for distillation, began work on a commercial scale at Bathgate, 1850. The deposit of Boghead mineral was exhausted in 1862 and then the extensive deposits of bituminous shale west of Edinburgh were utilized. The Torbanehill mineral yielded from 116 to 125 gallons of crude oil per ton, but the black shales only 40 to 45 gallons. The oil-shale industry was carried on for many years with varying success but, with improved methods of mining and distillation, and with more attention to the value of the by-products, especially ammonium sulphate, now much in demand as a fertilizer, and paraffin, the industry has become very profitable, some of the companies paying annual dividends of 50 per cent or more.

In 1904, the production of oil shale in Scotland was 2,709,840 tons yielding 63,000,000 gallons (Imperial) of crude oil and, in 1913

¹Sir Boverton Redwood, *Petroleum and its Products*, Vol. 1., 1st ed., p. 14.

²R. W. Ellis, *Oil Shale Industry of Scotland*, Mines and Geol. Survey Branches, Department of Mines, Canada, 1910, Nos. 55 and 1107, Pt. II, p. 41.

3,150,000 tons of shale were mined from which about 65,000,000 gallons (Imperial) of crude oil was obtained. From these figures it follows that the average yield of crude oil is from about 20 to 23 gallons (24 to 28 gal., U. S.) per ton. During the same years, the average amount of sulphate of ammonia produced per ton was from 35 to 40 pounds.

In Saxony, chiefly brown coal or an earthy lignite is used in the distillation of oil, and the industry, began more than half a century ago, has become very important. In 1880, the amount of lignite mined for the production of crude oil was over 9,000,000 tons but later statistics are not available. The oil-shale industry is carried on in a number of localities in New South Wales, which has some of the largest and most important deposits in the world. The material is called by different names, viz.: kerosene shale, torbanite or Boghead coal, cannel and parrot coal, etc. The yield of crude oil per ton from some grades is over 100 gallons.

Extensive deposits of bituminous and oil shales occur in eastern Canada, particularly in New Brunswick, Nova Scotia, and Quebec. The oil shales of New Brunswick are known as the Albert shales of the Perry formation of early Carboniferous age. The petroliferous character of these shales led to much fruitless drilling for oil and the high oil content of some of the bands of shale resulted in a thorough test being made under the direction of the Department of Mines of Canada to determine their commercial possibilities. Some 45 or 50 tons of material were sent to the Pumpherstons Oil Company near Uphall in Mid-Calder, Scotland and the shale, upon distillation, yielded about 48 gallons (U. S.) of crude oil and 77 pounds of ammonium sulphate per ton, or twice the average yield of oil and ammonia from the Scottish shales.

The value of oil-shale depends not only on the oil but also upon the ammonia content. The by-products, particularly ammonium sulphate and paraffin are the chief sources of profit. The failure of many of the early companies was due to the fact that they recovered the oil but not the ammonia. Investigations show, that, in general, as the content of oil decreases, the ammonia increases. From this fact, shales low in oil but high in ammonia can be made to yield a large profit and the low average yield of 20 gallons of oil per ton from the Scottish oil shales is due to the utilization of a greater amount of the "lean" oil-shales, high in ammonia. Some of the latter yield only 10 or 15 gallons of oil but from 60 to 70 pounds of ammonium sulphate.

The value^a of the crude oil according to 1910 prices would be \$0.025

^aR. W. Ellis, Joint Report on Bituminous or Oil Shales of New Brunswick and Nova Scotia Mines, and Geol. Survey Branches, Dept. of Mines, Canada, Nos. 55 and 1107, Pt. I, pp. 34-35.

per gallon and of the ammonium sulphate \$0.29 per pound, therefore the value of the products of distillation, i. e., 48 gallons of oil and 77 pounds of ammonium sulphate would be \$3.43 per ton. The cost of mining the shale is estimated at \$1.00 per ton and the retorting of the shale and the manufacture of the sulphate \$0.86, or a total of \$1.86 per ton, giving a profit of \$1.57 per ton, no allowance, however, being made for depreciation of plant and equipment and for interest on the capital invested. This profit may be materially increased through the refining of the crude oil itself, especially if it is rich in naphtha, burning oil, and paraffin.

The by-products resulting from the present methods of retorting and refining of oil shale are numerous and there is still much chance for improvement in methods and means of treatment. The latest types of retorts have greatly increased the recovery of ammonia from the shales. As stated previously, the average yield of ammonium sulphate for the past few years from the Scotland shales is from 35 to 40 pounds and, with the improved retorts, 60 to 70 pounds have been extracted from the same shales. The common products of manufacture and their principal uses are:

1. Permanent gases, mainly used for fuel.
2. Shale naphtha used for lighting and heating or power purposes.
3. Burning or lamp oils, especially adapted for continuous burning lamps.
4. Intermediate oils used for gas making.
5. Lubricating oils.
6. Solid paraffin, used for water proofing, insulation, and metal protection.
7. Still grease, used for grease making.
8. Still coke, used for fuel where smoke is undesirable.
9. Sulphate of ammonia, used chiefly as a fertilizer, especially for the growing of sugar beets. With the exhaustion of the guano deposits of south America and the impending exhaustion of the nitrate beds of Chile, ammonium sulphate is becoming of great importance as a fertilizer, especially as it contains about 20 per cent of nitrogen, or 4 per cent more than nitrate of soda.
10. Liquid fuel—the acid and basic tars together with the dregs and other residues are generally used as liquid fuels in the stills. These tars with further refining would probably yield a number of tar products.
11. The oil from some shale yields vaseline, but this substance is not contained in the Scottish oil shales.
12. "Spent" shale. The shale after it has passed through the

retort may be used in the manufacture of Portland cement, brick, and road metal.

The future value of the bituminous or oil-shale deposits has been recognized by the British Government and, according to reports, the British Admiralty has purchased a large tract of oil shale in New Brunswick to be held as a reserve for supplying the British navy with fuel oil when the present sources are exhausted. Recognizing that the present and growing demands made upon the oil fields of the continent must sooner or later exceed their capacity of production, the U. S. Geological Survey has made an investigation of the oil shales of Utah and Colorado to determine their possibilities as a future source of oil. The results of this investigation will be issued as a bulletin, which is now in press. According to the Press Bulletin of the Survey of January, 1914, the tests and analyses of the oil shales of these states show that they contain from 10 to 61 gallons of oil per ton with a probable average of a barrel per ton for the better grades. This is practically two and one-half times the average yield from the Scottish shales and compares favorably with the better grades of shales of New Brunswick. Apparently, the investigations did not extend to the nitrogen content of the shales which, as previously mentioned, is of the utmost importance in exploiting oil-shales on a commercial basis since much of the profit comes from the ammonium sulphate, the coming substitute for the guano of South America and the sodium nitrate of Chile.

In Michigan, there are a number of formations containing bituminous or oil bearing shales. The Antrim shale, 300 to over 480 feet in thickness, locally is composed almost entirely of black bituminous shales. In certain parts of the State, however, it contains much light colored shale. In Alpena and Charlevoix counties, this formation is easily accessible as it outcrops at a number of points and is under a light cover of drift in many localities. Even where the drift is of considerable thickness, as in southeastern Michigan, the shales could be easily mined for the formation generally contains little or no water.

In the Northern Peninsula the Utica black shale is about 50 feet thick and outcrops, or lies beneath a thin cover of drift in many places on the east side of Whitefish river, Delta county. In the Southern Peninsula, the formation is thicker, but is too deep to have economic possibilities. From 1851 to 1861, near Collingwood, Ontario, the Utica shales were used for the distillation of oil with fair success until the discovery of the Petrolia oil field. Numerous black shales also occur in the Coal Measures associated with the coal beds. Some of the coal seams are too thin or of too low grade for profitable mining, but it is possible that the coal, usually high in volatile matter, and

the black shales, or the bone, cannel, and "blackjack" coals could be mined together for their oil and ammonia content and made to yield a substantial profit. Certain parties from New York investigated the Michigan coals last year with the view of establishing a coal and shale oil plant and reported that some of the coals high in volatile matter were very suitable for the manufacture of oil and ammonium sulphate, but as yet nothing has come of the project.

The amount of oil or bituminous matter recoverable as oil in the sediments is many times that contained in the accumulations known as pools, and, in contrast to the latter, the amount of oil in a given area of bituminous shale can be estimated within close limits. The average yield of oil from the better grades of Colorado and Utah black shales is estimated at 53 gallons per ton or about 71.5 gallons per cubic yard. A square mile of such shale three feet thick would yield over 1,800,000 barrels of oil, and 300 feet thick 180,000,000 barrels, or more than 75 per cent of the total production in the United States for 1913.

If the oil is present in amounts of only one per cent, a square mile of rock 300 feet thick would contain 15,000,000 barrels of oil. While no extended tests and analyses have been made on the Antrim shales to determine their average oil content, the two analyses given below indicate that locally the content of oil is about 6 per cent, equivalent to at least 90,000,000 barrels per square mile, 300 feet thick. In any case, the amount of oil in the Antrim shale alone forms a reserve practically inexhaustible which can be drawn with the exhaustion of the oil fields of the country.

ANALYSIS ANTRIM SHALE.

Sample from a depth between 1575 and 1700 feet in the No. 2 Assyria well, Barry county. Analysis⁴ by a student under the direction of M. A. Cobb, laboratory of Lansing High School, October 22, 1903.

	Percent.
Moisture.....	6.595
Volatile carbon.....	6.025
Fixed carbon.....	3.95
Ash.....	83.435
Total.....	99.985

⁴Ann. Rept. Mich. Geol. Surv. for 1903, p. 277.

OIL AND GAS IN MICHIGAN.

ANTRIM⁵ SHALE.

Sample from near Alpena, Analyst, W. H. Johnson, Alpena.

	Percent.
Volatile matter (water between 5 and 10 percent).....	17.96
Mixed carbon.....	6.49
Ash.....	75.55
Total.....	100.00

While there are no satisfactory analyses showing the oil content of the Utica shale, the table of analyses taken from a report on the geology of Wisconsin shows the bituminous character of the shale.

	I.	II.	III.	IV.	V.
Clay and sand.....	38.45	34.60	37.26	48.27	73.57
Carbon.....	6.83	6.63	0.61	6.99	15.03
Hydrogen.....	0.74	0.77	0.88	1.13	1.65
Oxygen.....	3.20	2.96	1.71	3.39	5.39
Carbonate of lime.....	45.02	49.81	52.60	20.30	1.29
Carbonate of magnesia.....	2.09	2.53	3.42	11.48	0.76
Alum. and oxide iron.....	2.16	2.09	3.29	7.99	2.79
Total.....	98.49	98.89	99.72	99.55	100.48

No. I is a brownish black, very fine grained rock from Cape Smith, Lake Huron.

No. II from an island to the north of Maple Cape, Lake Huron and is blackish-brown, fine grained, and of earthy texture, with a laminated structure, and contains no fossils.

No. III from St. Anne, Montmorency, is a dark brown shale, and contains graptolites.

No. IV is from Gloucester, near Ottawa, and is a black shale filled with fragments of trilobites and crinoids. In these analyses, the carbonates of lime and magnesia, with the alumina and oxide of iron, were removed by solution in acids, and the elements of the organic matter were determined in the insoluble portion.

No. V is that of a pyroschist from this formation in the lead region of Wisconsin.

Dr. T. S. Hunt's⁶ account of the attempt to exploit the Utica shale for oil in the vicinity of Collingwood, Ontario, gives a general idea of its possibilities as a source of oil.

"These shales contain very variable amounts of combustible matter, and they give when distilled, besides inflammable gases, portions of oily matter, which in the shales of Collingwood, the richest yet

⁵H. Reis, *Clays and Shales of Michigan*, Geol. Surv. Vol. VIII, Pt. 1, 1900, p. 47.

⁶Geol. Surv. Can., 1863, p. 784.

examined, are equal to 4 or 5 per cent. Though the final results of the retorting of these shales are not now available the following details of operations at this place may be given (Geol. Can. 1863, p. 784):

In 1859, works for obtaining these oils were erected on the locality of this shale, near the town of Collingwood. Twenty-four longitudinal cast-iron retorts were set in two ranges, and heated by wood, of which 25 cords are said to have been required weekly. The shale, broken into small fragments, was heated for two or three hours, from eight to ten charges being distilled in 24 hours. In this way, it is said from thirty to thirty-six tons of shale were distilled daily, and made to yield 250 gallons crude oil, corresponding to about three per cent of the rock. By a further continuance of the heat, a small additional proportion of oil was obtained from the shale; but it was found more economical to withdraw the charge after $2\frac{1}{2}$ hours. The bed of shale available for the purpose adjoins the works, and was furnished, ready broken, at twenty-cents per ton. The cost of the crude oil from the shale was stated by the manufacturers to be fourteen cents per gallon. When rectified and deodorized, it gave from 40 to 50 per cent of burning oil, and from 20 to 25 per cent of pitch and waste, the remainder being a heavy oil fitted for lubricating purposes. After two or three unsuccessful trials, and the repeated destruction of the works by fire, they were at last, in 1860, got into successful operation, and a ready market was found for the oils. Data, however, is wanting to show whether the enterprise was remunerative; and it was after some time abandoned, partly, it is probable, on account of the competition of the petroleum of Enniskillen, which was about that time brought into the market in large quantities, and at a very low price. Should it, however, at any time be found advantageous to renew the experiment of distilling the bituminous shales of this formation, those of Collingwood offer very favorable conditions, from their accessibility, and also for the ready means of transport afforded both by the lake and the railway."

The following tables largely taken and adapted from the Joint Report of Mines and Survey Branches Nos. 55 and 1107 illustrate the difference in the analysis and in the yield of crude oil and ammonium sulphate from various oil shales and oil coals.

	Moisture.	Volatile Hydrogen.	Fixed Carbon.	Ash.
Torbanite, Scotland.....		*71.17	7.65	21.18
Albertite, N. B.		*54.39	45.44	0.17
Jondra oil-shale, N. S. Wales.....		*89.57	5.27	4.98
New Zealand torbanite.....	2.83	58.05	26.02	5.10
Kentucky Cannel Coal.....	1.21	55.86	35.17	8.26
Stellarite, Nova Scotia.....	0.37	68.38	22.35	8.95
Antrim shale, Barry Co.	6.595	6.025	3.95	83.435
Bone coal, Baginaw Valley.....	8.08	30.74	49.29	11.89
"Cannel" Arenac Co.	11.35	35.80	41.10	11.87
St. Charles, Baginaw Co.	2.37	38.18	58.99	2.46
English Cannel, Wigan.....		*39.64	57.66	2.70

*Dry material.

The figures given in the table below refer to the U. S. wine gallons and are the approximate equivalents of the figures given in the above report which refer to the Imperial English gallon.

	Crude oil, gallons.	Ammonium sulphate, pounds.
Geo. Irving seam, N. B. (shale retorted in Scotland).....	48	77
Albert mines, N. B.	32-58	49-82
Albertite, N. B.	135	65
Stellarite coal, Nova Scotia.....	60-150	
Baltimore shales, N. B.	55-68	30-112
Taylorville shales, N. B.	52-57	85-101
Utah and Colorado black shales.....	10-61	
Torbanite, Scotland.....	108-156	
Pumpherson seams, Scotland.....	19-24	55-60
Union oil-coal, W. Va.	32	
Elk River oil-coal, W. Va.	54	
Kanawha oil-coal, W. Va.	88	
Wolgan and Capertee, N. S. Wales.....	120	
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"Old Kentucky Boghead."		

In conclusion it may be stated that Michigan has an abundance of oil-shale and oil-coal which, with the increasing demand upon the oil fields of the country, probably exceeding their capacity of production within a very short time, and with the exhaustion of South American guano and nitrate deposits, will become of very great economic importance as a source of oil and ammonium sulphate.

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